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May 1964

Professional Guide Series:

INCORPORATION OF SHELTER INTO PARKING GARAGES

(Rough Draft)

Department of Defense
Office of Civil Defense
Washington 25, D. C.

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PREFACE

This Professional Guide is one of a series of technical publications prepared under the direction of the Office of Civil Defense. The purpose of the Office of Civil Defense Technical Publications Program is to assist architects and engineers in the planning and design of structures that contain protective features.

This publication was prepared for the Department of Defense, Office of Civil Defense, by the Small Homes Council - Building Research Council of the University of Illinois, Rudard A. Jones, Director; Brian J. Crumlish, Principal Investigator and Author. Members of the staff of the Small Homes Council - Building Research Council, along with certain members of the University of Illinois Department Civil Engineering, assisted in the investigation.

This publication is presented as an interim edition to meet the immediate need of architects and engineers, and to allow the professions to contribute their experience for consideration in preparation of the final version. Comments should be sent directly to the Protective Structures Division, Office of Civil Defense.

The Technical Publications Program consists of five categories:

Professional Manuals present the technology of design and review for protection against weapons effects.

Professional Guides orient this technology to the incorporation of protective features into normal use structures, such as: schools, apartment buildings, industrial plants.

Technical Memoranda present subjects not of sufficient scope to warrant presentation as a manual or guide. These generally consist of performance requirements for shelters and shelter components.

Design Studies present, in general outline form, suggested designs for incorporating protective features into normal use structures.

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Engineering Case Studies are engineering reports on the design and construction of specific projects.

Listing of publications now available are included on the inside covers of this guide. Request for copies should be made on company letterhead to the Protective Structures Division, Office of Civil Defense, Washington 25, D. C., or to Regional Offices listed in Appendix C.

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INTRODUCTION

The number of favorable points of current parking garage construction, with respect to natural resistance to the effects of a nuclear detonation, indicates that this type of structure deserves special consideration as a protective structure.

A building type introduced to American cities only a few decades ago, the parking garage now represents a significant percentage of new downtown construction; and as the popularity of automobile travel continues to rise, the need for more parking facilities naturally follows.

By demand, the parking facilities, easily accessible to the main traffic arteries of the urban area, are as close as economically possible to the center of the working population and the shopping areas of the large metropolises--areas where people are at some distance from their home or neighborhood shelters.

These structures, even on only a superficial examination, reveal inherent characteristics highly desirable for a protective structure. In planning layout, the wide ramping system designed for the rapid and convenient distribution of automobiles provides easy, generous access to a mass movement of people; the relative openness of the plan allows a high degree of flexibility in arranging space in emergency conditions. In construction, the structure is frequently both fire resistive and of a massive construction desirable for radiation attenuation.

It should be noted at the beginning that complete protection against all nuclear effects is impossible. However, certain degrees of resistance to each effect can be developed.

The prime objective in a good shelter program is to protect the population. As a shelter for citizens, a garage utilizing the principles of mass and geometry shielding could reduce the hazards of radioactive fallout to the shelter occupants; increased structural resistance and special attention to the detailing of openings could reduce the dangerous effects of the blast and thermal waves.

Another objective of the use of more protective structures is to lessen the burden of construction on the economy in a period of crisis. The erection of structures with a capacity to withstand thermal and blast effects would, in emergency conditions, not only provide a shelter during periods of high radioactive fallout, but would also provide temporary quarters in the event of destruction of offices or residences. Eventually, of course, it is ready to serve its peacetime use again, when the emergency situation has passed. In any case, attention should not be limited to structural parts; the mechanical systems should also be designed for as nearly an efficient continuous function as possible.

The additional objective of preserving material goods will also assist in relieving the burden on the economy. Protection of goods stored in a structure would not be a primary consideration in the design of a parking garage, but the availability of some vehicles in an emergency period would be an additional benefit. If the structure is to serve as a fallout shelter or emergency housing area, certain emergency goods must be stored and attention given to their protection. For example, the sleeping and food supplies must be protected from the possibility of ignition from thermal radiation, from devastation by blast pressures and from contamination by radioactive fallout.

Many of the problems to be solved are similar to those of other structures and they will not be dealt with in detail. The general emphasis in this Guide will be those problems that will be encountered particularly when designing a parking garage with protective features. In addition to those protective features which must be incorporated in the original construction, the designer should be aware of the temporary requirements that may be taken during emergency conditions. His design could make adaptation of them faster, more economical and efficient. Wherever possible, hasty measures (those accomplished in a few hours), expedient measures (those requiring a day or so of preparation), and improvised measures (those involving a week or so of construction) will be pointed out.

The establishment of exact design criteria is not the purpose of this Guide. The intensity of all nuclear effects on a structure varies independently--depending on distance from the detonation, the height and magnitude of the explosion, atmospheric and geographic conditions and so forth. A brief description of the phenomena accompanying a nuclear detonation has been prepared by the Office of Civil Defense and is included in the appendix.

Specific loadings or intensities as established by OCD such at 5 and 25 psi resistance qualifying as "limited" and "blast" protection, and a minimum protection factor of one hundred for fallout are not necessarily implied in the examples. In some cases the expense or complications involved will not allow the attainment of these criteria; yet some percentage may be provided. In other cases, higher degrees of protection may be gained at a very moderate expense.

Garage structures are frequently limited to minimum budgets. Throughout this Guide, protective features are carefully considered for their effect on both the economical and efficient operation of the structure in its peacetime function to store automobiles as compared to the advantages gained in its alternate use as a protective structure.

Certain garage types are inherently better suited for protective structures; other types will require the incorporation of special protective measures. In all cases, inclusion of some protective features should nonetheless be investigated.

The discussion of cost is kept in a relative nature on each feature and a detailed cost analysis is not included. As an example of cost analysis, the designer should refer to the design studies and engineering case studies (OCD DSG 35 series).

The general emphasis of this Guide is to discuss ideas which the architect or engineer may or may not accept in his design of a parking garage structure. It is hoped these ideas will furnish sufficient background to the designer so that he is better able to determine the amount and type of protection he may wish to incorporate into a structure.

CHAPTER I

THE PARKING GARAGE

1-1 General

This chapter discusses the demand for parking space as related to city planning, population densities, location and the basic types of parking structures emerging from the demand.

1-2 The Parking Garage and the City

1-2.1 Parking Demand and City Size

The parking garage is essentially a planning device used to concentrate the storage of automobiles in areas of heavy traffic generators. This type of structure occurs most frequently in areas where land costs are high. The major purpose of this structure, accommodating the storage of automobiles, is not to shelter vehicles but to gain maximum use from the land. The storage capacity of an expensive parcel of land can be increased as much as ten times by the use of multi-level garages; a dual use of the land may be accomplished by combining a parking garage with another more profitable type of structure; or the land is freed as open space when an underground garage is built.

In small cities where the cost of land is low, the areas of dense traffic are frequently limited to the vicinity of such generators as shopping centers and small businesses. Adequate parking space is usually available at curb parking in towns less than 10,000 inhabitants with the growth of a city, however, the street pattern seldom changes and the amount of curb parking consequently does not increase. Off-street parking spaces begin to appear as the city grows but rarely do economic factors demand parking garages before the city reaches a population in the neighborhood of 100,000. The parking garage is a phenomena of large cities. Rarely is a new structure added to the urban scene without some measurable impact on traffic and parking problems.

The area devoted to automobiles for parking in a new project depends upon the nature of the project. This area often equals or exceeds the area assigned to the major function of the project. In residential projects such as private homes, apartments, hotels and motels, space for one or two cars per unit is customarily provided. Stores and offices require one parking space for every 200 to 400 square feet of leasable floor space. In places of assembly such as theaters, auditoriums and churches, the area required for parking frequently exceeds the net area of the assembly structure.

1-2.2 Parking as Part of a Coordinated Plan

Many new structures are, however, erected without regard to the parking demands or traffic pattern. Retail merchants are not financially able to construct parking structures. Alternatively, space must be provided in privately erected and operated garages or responsibility must be assumed by the city government. Where private garages are constructed, they are seldom established with respect to the traffic pattern. More often than not these garages are erected on low cost land inconvenient to both the major traffic arteries and the ultimate destination of the public using the facility. Cities are becoming increasingly more aware of this problem and are placing less reliance on private parking interests to assist in solving the crisis.

Another major factor affecting the parking pattern is the expansion of the rapid transit facilities of a city. The direct effect of an efficient rapid transit system is the diversion of automobile traffic from the center of the metropolis. Consequently, parking spaces must be provided in the fringe areas convenient to the origins of the service.

In order to achieve maximum efficiency, the planning and control of parking should be coordinated with the traffic layout, the land use and the rapid transit design. This can be best accomplished if these duties are assumed by a planning organization of the city. In addition, it seems reasonable to assume the planning of a city should be concerned with problems of sheltering the citizens from an enemy attack. If a parking structure is used for shelter, Civil Defense activities can be coordinated with the traffic design by the planning departments.

The principal problem in establishing a coordinated parking plan is usually the acquisition of land. Private ownership occasionally finds the solution is provided by the demolition of older buildings where the tax on structures makes it more profitable to convert land into vacant sites available for parking. In the cases of city government parking programs, it is not uncommon for the city to condemn the land, build the parking structure and then to finally lease the facilities to private operators.

As the need for parking increases in the heart of the city, the land available becomes increasingly scarce. Within the central business district, densities are high and the land precious. This is the hub of commercial activities of the urban area--a consolidation of offices and retail shops frequently surrounded by a ring of light manufacturing.

The area generally referred to as the core of the central business district, where densities and land costs are highest, occupies about a fourth of the central business district. It is the destination of the majority of shoppers and workers, but unfortunately contributes only a small fraction of the parking facilities at the present time. The pattern of growth in the core, encouraged by high land values, has been towards taller buildings which in turn generate more traffic. This traffic eventually forces the elimination of curb parking and the high land values icrease the difficulty of providing off-street parking.

1-2.3 <u>Parking Structures as Part of New Projects</u>

This intense problem has produced many creative solutions.

Interesting architectural solutions are being erected as an aid to eliminate the congestion of traffic and parking. As a result of planning studies, most large cities are programming enormous parking facilities in the very heart of the city, conveniently located for shoppers and workers. Private interests have also provided excellent examples of structures which include built-in parking among their client attracting facilities. The schemes are worth examination not only as good architecture and as solutions to the parking problem but also for the potential they hold as a significant element in a fallout shelter program.

Among the various solutions proposed to provide parking within the core, the scheme under consideration in the Seattle plan which proposes a dramatic pedestrian platform covering twenty blocks, is an excellent example of a very well protected area available to thousands of people. The unobtrusive parking, concealed in several layers below the surface of the plaza, returns a dignified aspect to a city threatened by the blight of automobile parking. Similarly, in Penn Center in Philadelphia, the automobile is skillfully restricted from the scene. Here within the broad open esplanades of the center a complex transportation innovation is included. All modes of transportation come together in a single structure which also houses six decks of parking to serve the area. In Rochester, the project of revitalizing the core of the city provides for a three-story parking garage built below grade with ramps linked to a surrounding link road and an eighteen story tower with banks, stores, offices, restaurant and hotel space.

Though somewhat smaller in size, the parking innovations provided by private enterprise are nonetheless imaginative. Private parking garages are not uncommon in the central business districts as part of office buildings, apartments, and hotels.

In Chicago, twin towers containing almost nine hundred dwelling units have a parking space for each unit on a continuous spiral ramp system on the lower sixteen floors. In many large cities co-op and high-rise apartment buildings have ramped underground parking garages.

Office building solutions have used a variety of schemes to provide parking in order to attract clients. A new skyscraper in Montreal is superimposed on a marble paved multi-level base which houses over two thousand cars. An office building in Kansas City has provided parking for its tenants with a five level above ground structure joined to the office building by a pedestrian bridge. In New Orleans, where the water table is near the ground surface, an elevated plaza screens an "underground" parking garage.

As a very active area of construction, Urban Renewal also furnishes many examples of interesting parking structures. Many cities are in fact utilizing renewal schemes as a means of providing some relief to the parking problem of the city. Expansive parking facilities within a project close to the business district serve both the inhabitants of the area and the people in the outlying areas expected to use them when in town on business or shopping.

At LaFayette Park in Detroit, a multi-level parking structure has been constructed between two 22 story apartment buildings. Appearing as a brick-walled horizontal slab, topped by a terrace and swimming pool for the 300 families, the structure conceals 370 cars.

In the new Carl Sandburg Village in Chicago, no traffic penetrates into the new housing and shopping center and all parking is underground. The considerable extra expense was justified by the creation of an atmosphere of quiet.

The areas surrounding cities provide fewer examples of parking structures. Parking garages in fringe areas are not generally successful as shoppers or businessmen prefer to pay a little more to park within walking distance of their destination. Of course, many housing developments provide enclosed parking facilities, but in general parking lots are sufficient.

In suburban areas large concentrations of cars occur at shopping centers; but without the pressure of high land costs, parking is usually allowed to cover the landscape and rarely is it housed in parking garages. The chief motive for housing automobiles in the suburbs is not land conservation but aesthetics.

A noteworthy example, which also testifies to the ubiquity of the parking garage structure, is an office building standing alone on a rolling 100 acre site in Connecticut. The elevated square doughnut of offices surrounds a covered ground floor garage. The roof of the garage forms a landscaped entrance court. The solution solves the vexing problem of what to do with employee cars in a rural setting. With the building raised above the ground, cars can be parked underneath it, minimizing walking distance and providing shelter from rain for employees or visitors leaving their cars in bad weather. Unsightly parking fields are eliminated so that panoramic views from inside the building, already enhanced by elevation, are not interrupted by the usual sea of automobiles.

1-3 Current Garage Construction

1-3.1 General

In such a rapidly changing field of design, generalization can be misleading; however, in order to make the guide most useful, some attempt has been made to determine which garage characteristics are most common current construction or promise to become so. Dimensional layout of a structures, for example, are greatly modified by structural innovation and by the constantly changing dimensions of the automobile. Area requirements reflecting these standards may be valid for only a few years.

1-3.2 Garage Types

Current garage construction may be classified by the method of management, location within the structure or method of inter-floor travel. Of these, the location of the parking facilities in the structure has the most influence on the effectiveness of the garage as a shelter, but the management and vertical circulation system have an influence on the usefulness of the structure as a shelter.

Type of management reflects both in the amount of space devoted to other uses and in the location of the structure. These factors may in turn influence the usefulness of the structure in a Civil Defense program.

If the garage is exclusively a commercial enterprise, privately owned and operated, it is unlikely, as previously pointed out, to be placed in a location determined by the community planning organization. This does not mean it cannot be utilized for shelter purposes but only that its location may not be the most desirable. Since commercial garages most probably charge fees on hourly, daily, weekly or monthly basis--the main floor will have enclosed areas devoted to offices and customer facilities. Frequently prime space on the main level is leased to another income producing facility.

A municipally planned parking facility erected by the city may be either city operated or leased to a private party. When operated by the city it may or may not charge a fee, but it is almost always a self parking facility. When operated privately, it may or may not be a self parking facility, but fees are generally charged.

A private parking garage is that type usually used in connection with another building function and provided for the convenience of the tenants. Usually the client parks his own vehicle and parking fees are usually included as part of the rent for the office or dwelling unit.

Parking facilities are also classified with respect to location in a building. The most representative structure of a commercially operated garage used solely for parking is the above ground structure. This is usually a multi-level structure and may be either an open air or closed type.

The open air structure is less vulnerable to blast pressures as a result of its open construction but offers the occupants less protection to thermal radiation and fallout than the blast vulnerable enclosed structure. As an above ground structure that is most likely to remain standing within the destructive area of blast pressure, the open air garage could best serve as a fallout shelter available to the occupants of nearby blast shelters.

Above ground garages are the most common type and in the immediate future probably will continue to represent the majority of parking garages. Unfortunately, the open air type possessing the fewest protective features is the most popular. Almost no above ground enclosed garages are being constructed except as integral types where the parking is enveloped by an office building or hotel. The enclosed type could be developed into an excellent shelter.

It cannot be expected that the expense involved for massive exterior walls, forced ventilation and lighting will be met without some incentive. This type of structure perhaps will be built in those locations where the prime motivation is to build a shelter with an alternate use as a parking garage.

The below ground garage structure has no operating advantage over the above ground structure. In addition to requiring more light and ventilation, construction costs below ground of a structure of this type usually exceed that of above ground. As a consequence, this type of solution is used only where underground space can be easily and cheaply acquired. The main advantage to using this design is that the ground surface is open for its original use and the cost of the land may be considered free. The below ground structure combines the protective advantages of the least vulnerability to blast along with the best thermal and radiation protection. It is uniquely qualified as a shelter.

Examples of the completely underground type occur in large cities--usually under public space. The most common type of garage privately underground owned is that located basement space of an office or apartment building.

A combination of both above and below ground parking is occasionally used. Because this usually requires two sets of ramps on the main floor (depending on the method of ramping) combination schemes are not usually economical. Under emergency conditions, the below ground portion could serve as a blast shelter and the above ground floors later as a fallout shelter.

Whenever the structure is adjacent to a sloping street, direct access is used for all floors. Thus, on a sloping site, above ground and below ground space is accomplished without the use of interior ramps since the structure may be entered at several levels. Costs can be kept low because by the usual code definitions the structure is open-air and no mechanical ventilation is required.

An integral structure includes provision for parking within a structure intended for other purposes. This is rapidly becoming popular in office, hotel and apartment structures. There are positive advantages for this type of structure as a shelter. When the parking is enveloped within another structure, the shelter area gains in protection from the surrounding walls. There is also convenience to all the utilities of adjacent structure.

1-3.3 <u>Interfloor Travel</u>

Vertical circulation within the structure may be either by ramps or elevators. If ramps are used, considerable space is taken by them on each level. Though this limits the usable space for parking, the ramps may be used for shelter space since their slopes are low. The fact that the ramps demand a large building is an advantage to this type for shelter considerations. The minimum size garage that can be designed with ramps is approximately 110' x 160'. In this design, however, over two-thirds of the area is taken by ramps--a very uneconomical ratio of circulation space to storage. The larger the lot, the more economical a ramping system becomes.

A garage using an elevator for vertical circulation requires only about twenty-five per cent of the area to be devoted to elevating devices. The structure can be placed on minimum lot widths as narrow as twenty-four feet if there is access on two sides. This type is most suited for very costly sites. The relative openness and typical narrowness of a building using elevator parking usually eliminates this type as one suited for shelter purposes.

The ramping systems that may be adopted in a ramped garage are numerous and the selection should be based primarily on the proportions and space available. Ease of construction, area required, number and sharpness of turns, length of path of travel, separation of traffic and numerous other advantages or disadvantages of the various ramping methods has little influence on the protection afforded by the structure. The openings into the ramping system are the only critical considerations.

1-3.4 Size

Parking capacity of structures varies with the facility associated with the garage. However, even the small garages have a large shelter capacity if the structure is of protective construction.

Ramped structures usually do not exceed about five stories in height above grade for commercial installations since additional stories require critical travel time regarded as an inconvenience to the customer. Eight is the approximate limit in story height and two, of course, the minimum. With respect to the radiation protection, the taller structures are preferable since they offer greater overhead mass shielding and more area for shelter purposes.

1-3.5 Auxiliary Facilities

Private garages have few, if any facilities within the parking areas. Commercial garages usually include facilities for the convenience of customers, but these are limited to the ground floor. About half of the garages now being built include some rentable space on the street level with the remainder of this level accommodating circulation, administration and temporary storage space. Parking space is negligible on the ground floor in most designs. The ground level of integral structures is usually used for lobbies or terraces. The other floor levels are typically open space, uninterrupted except by vertical circulation elements.

The space therefore generally available for shelter will be open with no definition of smaller areas. Auxiliary features located on the main floor generally are not useful because they will not have a high degree of protection.

1-3.6 Structure

Although, for flexibility, long spans are recommended for parking garages, the majority of the commercial garages built use a structural grid varying from twenty to thirty feet square. This bay size is based on an economical structural span modified by the stall layout, angle of parking and circulation system using the current car dimension. Reinforced concrete is principally used for the structural system but precast shapes are gaining in popularity. Exposed structural steel is generally limited in application to open-air elevator structures where local code permits its use. In parking garages located beneath other buildings, the structural bay is frequently a projection of the bay size selected for the superstructure.

The reinforced concrete structure commonly used is preferable for radiation shielding because of its mass. Long spans, however, should be minimized because of structural behavior under blast loadings. Precast sections will require additional expense to achieve continuity over joints.

CHAPTER II

DESIGN STANDARDS OF THE GARAGE STRUCTURE

2-1 General

The successful design for a parking garage incorporating protective features involves the satisfactory solution of several design criteria. For the peacetime use of the structure the architectural solution must solve the approach, the manuvering, the parking and the storing of vehicles, as well as the special facilities required for the employees and the customers. This must be solved in a manner which does not endanger the health or the safety of the public in a manner as outlined by the building codes. In addition the new criteria demanded for resistance to nuclear effects must be included in the design.

The following chapter summarizes briefly these design requirements and comments on those which have some bearing on the usefulness of the structure as a shelter.

2-2 Garage Criteria

2-2.1 Main Floor Requirements

The main floor of any parking garage, whether it is a commercial or private facility is devoted to, at least partially, the requirements of receiving and dispatching the vehicles since the entrances and exits of the structure penetrate at this level.

These entrances are laid out on principles similar to those applied to intersection design; that is, they are designed so that the cars may enter and leave the garage either at a right angle to the traffic or be able to merge with the traffic. They are designed for relatively low speed operation admitting cars easily without any danger of collision and with clear sight lines for both traffic and pedestrians. Entrances should be located as far as possible from street intersections. Double or even triple lanes are preferred with each lane at least twelve feet wide.

Width requirements of lanes ideally suit the garage entrances to the mass movement of people. As discussed later a merging type of exit may be a better solution for blast resistance. It should also be noted that the clear site lines requirement will automatically eliminate certain areas as fallout shelter areas.

Immediately after entering the garage, a large space or reservoir area should be provided to absorb peak in-bound traffic, and a place of temporary storage. The extent of this area depends upon the type of garage planned. If it is to be a self parking facility the cars will move through the area rapidly and only a small space need be provided for distribution of tickets. In a commercial garage with attendant parking the size of the reservoir, which in most cases exceeds space for ten cars, is dependent upon the calculated rate of car arrival in the peak parking period, the average time for parking and the number of parking attendants. In laying out the reservoir area, the design solution should conveniently form a transition between the entrance and ramps. If the driver leaves his car here, the area should be designed for pedestrians to circulate safely and it should be convenient to the customer facilities.

If the garage is a commercial type are located on the main floor adjacent to the reservoir area facilities which require public contact. Because of the commercial value of this space they are kept to a minimum. The cashiers booth, for example, should be as small as practicable-issuing tickets and collecting fees while bookkeeping and personnel administration should be housed in less valuable space. Public telephones, restrooms and check rooms and essential customer facilities as well as some optional facilities such as manager's office, service and repair and sales are also located on the main floor.

This reservoir space which serves as a registration point for motorists could very easily serve this function also in a shelter. Located adjacent to the office and waiting facilities and of a large area, it could be a useful area in processing the entering shelter occupants. The typical arrangement of placing these facilities on the ground floor should be reconsidered if the structures are to serve as a fallout shelter. Ramping down a level before entering this area could bring it within the shelter area. This would lessen the number of leasable car stalls but would increase the rentable ground floor space.

From the reservoir area, the flow of the traffic leads directly to the ramps. The ramp location is primarily determined by the layout of the storage floors. It should be designed so that termination on storage floors will permit efficient parking and travel arrangement. On the main floor development of maximum reservoir space would ideally place the ramps at a maximum distance from the entrance. For both efficiency and ease of travel ramps should have grades between ten and fifteen percent. A twenty percent grade is permissible for short ramps such as those used between staggered floors. All ramps should be eased to six percent grade at both the head and foot. Width of ramps should be ten feet per lane and dividing strips between lanes should be eighteen inches.

Of the many ramping systems available preference should be given to separate ramps for the two directions of travel rather than combining the two. During the critical time of entering the shelter a single lane would still be sufficient to handle the mass movement. Then, if it is decided to evacuate automobiles, confusion and even panic may be avoided by having separate and distinct lanes for the outgoing cars and the incoming shelterees.

2-2.2 Storage Floors

The principles of layout of a storage floor are evolved from the basic units of design: the car stall and the access aisle. The ideal layout of a floor is a maximum number of spaces with a minimum interference and restriction to car movement.

With the constant change in automobile sizes, the stall size also changes. Currently an eighteen foot length will accommodate 95% of all cars. Six and a half feet of car width with one foot of clearance on both sides for movement are minimum stall widths. Eight feet is used in commercial parking garages where the attendant parks the vehicle and eight and a half feet where the owner parks his own vehicle in either a commerical or private garage.

Parking angles vary from 30 to 90 degrees. Ninety degrees is generally the most economical for a number of reasons. It is easier to coordinate the layout with the structural grid, the access aisles can be used for two-way movement, and dead-end aisles can be employed. Aisle widths are dependent upon the direction and angle of parking and the turning radius of the vehicles.

The total area per auto depends upon stall width used, angle of parking and whether head in or back in parking is used. For example, an 8'-6", 30° head in stall requires 363 square feet per stall and aisle as compared to 240 square feet for an 8'-0" 90°, back in stall. For preliminary design purposes, 300 square feet per automobile is generally used. These figures do not include main circulation aisles.

2-3 Building Codes

2-3.1 <u>Scope</u>

Building codes are prime instruments in the evolution of a building type. In a building type such as a parking garage, codes are a control and safeguard for the public where hazardous conditions could exist. The rather strict set of rules evolved for this building type has become the criteria for design rather than merely an acceptable minimum. Some items required by codes will limit the construction to such a degree that the structure cannot effectively be used as a shelter unless protective measures of a temporary nature are planned.

Almost all the large cities where parking garages are being built have published building codes. Stipulations set forth by them have been summarized by the examination of three basic codes.

The following codes were examined as representative of current code requirements:

The National Building Code

The Basic Building Code of Building Officials Conference of America

The Uniform Building Code

2-3.2 Definitions

A parking garage is generally defined as a building or structure or a portion of a building in which motor vehicles containing a flammable fluid in its fuel storage tank are stored. It may be an enclosed or an open air structure. An enclosed parking garage means a garage having exterior closure walls and an open air parking garage is defined by almost all codes as one having not less than 50% of two sides of the garage open to the air at each story. If an enclosed parking garage is located in a story with one-half or more of its clear height below grade it is defined as a basement parking garage.

A parking garage does not include any areas for motor vehicle service or repair, and the parking of busses, trucks or similar vehicles is not permitted.

2-3.3 Adjoining Uses

Unless the exterior walls are of fire resistant construction and are without openings, a parking garage must not be located adjacent to property lines. If the structure is an open-air type, any wall with openings must be at least fifteen feet from any line where another structure might be built. Open-air garages cannot be located within or attached to a building used for any other purposes unless separated from the other use by fire resistant construction.

2-3.4 Area and Height Limitations

Requirements restricting height and area vary considerably among the codes. The codes are consistent in permitting unlimited height and area when fireproof construction is used. In open air non-combustible construction, height limitation vary from five stories to eight stories and area limitations from 12,000 to 30,000 square feet. Increases in both height and area are permitted by some codes if open air construction is used on the third and fourth sides of the structure or if a sprinkler system is added to the garage.

2-3.5 Other Occupancies in the Structure

All codes prohibit any other occupancy within or attached to an enclosed parking garage unless separated by barriers of non-combustible material and unpierced by openings except doors equipped with self-closing devices. Small areas such as offices and salesrooms are permitted if they are constructed of a material resisting the passage of smoke, gas or odor.

2-3.6 Structure and Materials

Live loads in most codes are established at 100 pounds per square foot and no reduction is permitted of live loads in structures for parking motor vehicles.

The construction of enclosed garages must be of non-combustible materials and open-air garages shall be of fire-resistive construction. Codes further require that the floor surfaces shall be of non-combustible material without pits or depressions and shall be graded to drains. Non-absorbant, non-combustible materials such as concrete are required for floor finishes. Parking on roofs is limited to structures of fire-proof construction. Roof parking further requires parapets and wheel guards. Adequate curb and guard rails must be provided at openings in exterior walls in open air parking garages.

When basements of public garages are used for purposes other than parking, access shall be from the outside only and the first floor construction must be fire resistant and both water and vapor proof.

2-3.7 Means of Egress, Stairs and Ramps

Only one exit way is required for each story of a structure of fire proof construction. If the structure is fire resistive construction, parking more than sixty vehicles per story or of less than fire resistive construction and parking more than forty-five vehicles per story, two separate exit ways are required. If mechanical parking is used in an open-air structure, only one exit way is usually required for each floor. Ramps which are not considered as required exits need not be enclosed in garages of fire resistive construction, non-combustible construction or in sprinklered garages.

2-3.8 Openings

Where the exterior enclosing walls are omitted in an open-air structure, it is not permitted to close, partially or completely, the opening with glass or tarpaulins. Openings from garages into spaces for other occupancy are to be equipped with self-closing fire doors.

2-3.9 Lifts

In an enclosed structure all vertical shafts for elevators or vents must be enclosed. In open parking garages, lifts used only to transport employees may be installed and these need not be enclosed except with a protective wire mesh.

2-3.10 Heating and Ventilation

In enclosed buildings used for parking automobiles operated under their own power, exhaust ventilation shall be provided sufficient to produce one complete change of air every 15 minutes. Such exhaust ventilation shall be taken from a point at or near the floor level.

When garages are located below grade they must be ventilated by a mechanical ventilating system with positive means for both inlet and exhaust. Requirements for air changes can be as high as eight per hour. Mechanical ventilation may be omitted in small parking areas (5000 square feet or approximately twelve cars) if the space has unobstructed openings to outer air sufficient to provide necessary ventilation.

In those areas of the structure not used for storing automobiles such as the offices and waiting rooms, light and ventilation must be provided either naturally or artificially. In no case shall less than two changes of air per hour be provided.

If the structure is enclosed and heated all heat generating plants except direct fired heaters must be located in separate buildings or must be enclosed within the structure with solid, water and vapor tight masonry. Entrance must be from the outside since no openings are permitted through the fire division.

2-3.11 Fire Protection Equipment

Sprinkler systems are required for enclosed garages over 65 feet high exceeding 10,000 square feet per floor if of fire resistive construction or 8,000 square feet per floor if of protected combustible construction. Open air garages over 65 feet in height and exceeding 15,000 square feet per floor in area also require a sprinkler system.

If the building is less than 75 feet a one source system may be used in buildings of which the upper stories are designed for other uses when the garage has a capacity of more than twenty automobiles. If a building is more than 75 feet high, a two-source system is required.

In addition to automatic fire-extinguishing systems, at each stair and lift opening on each parking level, a manual fire extinguisher must be installed.

2-3.12 Toilets

If both sexes are employed in the garage, there should be two toilet rooms located within the structure. The number of fixtures is dependent upon the number employed. Toilet facilities for the convenience of the customers is not required. Four air changes per hour are required for toilet rooms.

2-4 Nuclear Effects Resistance and Shelter Requirements

2-4.1 Scope

The previous sections discussed the design criteria of a parking garage intended for use under normal conditions relative to their effect on a shelter structure. To these must be added the specific design criteria for resistance to nuclear effects and the requirements of habitability if the structure is to serve as a shelter. Knowledge of the details that increase the effectiveness of the structure to withstand certain nuclear effects and to protect occupants can be used to take full advantage of all the inherent protection in the structure.

At the beginning, the designer should decide how the structure can best be used in emergency and then orient his improvements towards that type of solution. Aside from the peacetime function as a parking garage, the building could serve in three different capacities during an emergency period:

1) Designed to act as a shelter during the blast and thermal waves and also during the subsequent period of fallout--in which case, all phases of nuclear effects must be considered.

2) Designed to remain standing through the blast and thermal waves and only after this be utilized for shelter purposes.

3) Designed to serve as a fallout shelter on the assumption that the intensities of both the blast and thermal waves are negligible. The attention given to various nuclear effects depends on which type of protection the building is intended to offer. Equal resistance to all nuclear effects cannot easily be established since the intensities of all nuclear phenomena vary independently. Certain assumptions must be made for each hazard and they can best be examined independently.

2-4.2 Thermal and Intensities and Fire Hazards

Approximately one third of the energy released from a nuclear detonation is in the form thermal energy and travels outward in a straight line in all directions from the explosion. Traveling at the speed of light it is the first effect to reach the area surrounding the target. The amount of the energy received, the time period over which it is applied, and the ignition point of the material receiving the energy will determine the probability of fires that may result. The danger from the thermal pulse is not directly related to the possibility of blast and radiation effects, and, therefore, the designer should not attempt to establish an exact amount of energy that may be received on a given structure. These thermal intensities received as a direct result of the thermal pulse are usually not sufficient to cause ignition of fire resistant structures such as parking garages. Instead, the chief danger results from the ignition of more flammable materials in the neighborhood or in the interior of the structure.

Indirectly, fire hazards also exist as a result of blast effects. A fire may be caused within a structure that is otherwise isolated from flammable material as a result of electrical short circuits or gas lines damaged by the blast wave.

It should be pointed out that thermal intensities which might not cause severe damage to a structure could be extremely dangerous to occupants. Therefore, if the structure is intended as a shelter, special attention should be given to shield the occupants from the heat wave. This shield need not be massive, as any material which casts a shadow will offer protection.

Automobiles should also be shielded as they could possibly ignite as a result of exposure to the thermal wave. One of the main hazards of the automobiles is the fabric upholstery. At tests in Nevada, thermal radiation ignited the upholstery and caused fire to spread in exposed automobiles. In addition, in a simulated parking lot, much of the damage to glass, paint, and interiors was due to fires caused by thermal radiation. Gasoline tanks of the parked vehicles are not particularly vulnerable to direct ignition from the thermal pulse, as they are shielded from exposure by the automobile bodies.

The design of a structure less vulnerable to thermal and fire hazards may be summarized by the following design principles:

Planning and material selection should be based on good fire prevention standards.

The occupants and vehicles should be shielded from exposure to the thermal pulse.

Materials that will not sustain combustion should be used on exposed surfaces of the exterior.

Exposed flammable materials should be shielded.

The structure should be isolated from other elements that have low ignition points where possible.

2-4.3 Blast Effects

The rapid expansion of air caused by the high temperatures of the detonation causes a front to move outward from the explosion at approximately the speed of sound. This front will pass through the area surrounding the target shortly after the thermal pulse. The high pressure behind the shock front relative to ambient pressure is referred to as overpressure and may be of magnitude possessing ability to cause much structural damage. This overpressure, when striking on a surface results in a reflected overpressure. The overpressure is then amplified to a higher degree varying with the angle of incidence between the shock front and the surface. Following the overpressure front is the dynamic pressure of the wind associated with the subsequent movement of air. Because the location of the garage relative to ground zero is unknown, the exact loading imposed upon the structure cannot be predicted. Accordingly design loads for blast analysis are usually established from an assumed value of peak overpressure.

The effects of blast loadings on a garage depend on numerous conditions, but chief among these is the position of the structure relative to the ground surface.

In an above-ground enclosed structure, the difference in lateral loading resulting from the reflected overpressures on the front wall tends to move the entire structure because of the lack of equalizing pressure on the rear wall. Large buildings are more subject to this translational loading because of the time required to engulf the building.

In an open type of above ground structure, however, the loadings by the overpressures, reflected overpressures and drag forces may be substantially reduced. The amount of reduction depends primarily on the percentage of area of the wall that is open and thereby permits the blast wave to pass through the structure.

In an underground structure, the blast induced forces experienced result from the surface overpressure wave passing over the structure propagated through the soil.

In addition, plan configuration and building orientation have an influence on the amount of blast energy imparted to the structure.

As in the case of thermal radiation, it should be mentioned that increasing the structural resistance of a structure does not necessarily provide blast protection to the occupants. Moderate structural resistance can be developed to resist 5 psi overpressure at moderate expense. Overpressures below this are not generally fatal, but at these pressure levels, secondary effects of blast are still quite hazardous. At less than 1 psi, the shattering of glass and flying debris present problems that must be considered if the structure is intended to protect occupants during the period immediately after a detonation.

Automobiles and buses have been exposed to several of the nuclear test explosions in Nevada, where the conditions, especially with respect to damage by fire and missiles, were somewhat different from an actual attack. In most cases it was not primarily overpressure, but drag forces which produced damage to the vehicles. At a peak overpressure of five pounds per square inch, motor vehicles were badly battered, with their tops and sides pushed in, windows broken, and hoods blown open. However, the engines were still operable and the vehicles could be driven away after the explosion.

In shelter design, the following certain principles will help increase the protection to blast effects:

Protect occupants from flying debris and shattering glass.

Protect occupants from hazardous pressures.

Select material that will insure ductile response.

Design to achieve maximum continuity in the structural frame.

Avoid unnecessary frangible materials, projections, and fixtures.

2-4.4 Nuclear Radiation

The energy given off from an explosion in the form of nuclear radiation may be either prompt or residual. Prompt radiation has a limited range and within the effected area has a high intensity and is very hazardous. The area covered by residual radiation in the form of radioactive fallout represents the largest area covered by an effect of a nuclear detonation. Hazardous levels of fallout can be expected in the downwind direction at distances up to several hundred miles - considerably beyond the range of hazardous thermal radiation and blast levels. Up wind, or in the case of an air burst, the hazards of residual radiation may be less critical than those of thermal radiation and blast. Since the pattern is variable, the exact intensity cannot be predicted. The general practice is to assume a degree of protection and design the structure to that standard.

None of the types of nuclear radiation emitted has notable effect on the physical characteristics of either the building material or the motor vehicles. Radioactivity does not alter the structural properties or the appearance of the material exposed and the materials that attenuate radiation do not in turn become radioactive. However, all types of nuclear radiation resulting from a nuclear detonation are harmful to human beings, though they cannot be sensed except in very high intensities.

If the parking garage is to serve as a fallout shelter, certain design principles providing protection against radiation should be incorporated into the design. Protection may be accomplished by placing a shield between the source and those to be sheltered, or by reducing the intensity of the contributing source. Protection using a shield may be accomplished either by the use of geometry or a barrier. A complete description of the method of analysis of the two types of shielding is given in the Professional Manual 100.1 "Design and Review of Structures for Protection From Fallout Gamma Radiation".

Geometry shielding is protection offered due to distance from the source. The dose decreases with distance in a relationship dependent upon two factors. First, there is a decrease due to the spread over larger areas as the radiator travels and then there is the absorption and scattering of the rays by the intervening atmosphere. To take advantage of geometry shielding, the designer should select a shelter location with maximum distance from the source of contamination. The central areas of a structure are at a maximum distance from the ground contribution; and, the lowest levels are a maximum distance from overhead contributions. In multi-level structures, such as some parking structures, intermediate floors offer better shelter area. Located several levels below the overhead contribution they are still several levels above the neighboring ground contribution.

Barrier protection is achieved by application of the principle that rays are absorbed or attenuated in the course of their passage through any material. Decrease in radiation intensity is dependent upon the mass of the material between the source and the point of observation. A substance of low density requires a greater thickness than one of a high density. To take advantage of barrier shielding, the designer should select massive materials in preference to lighter weight ones where economically feasible and the massive materials should be utilized to define the shelter area.

Without altering the protection factors, the amount of radiation received in a protected area may be substantially reduced by partial removal of the fallout material in the area surrounding the shelter. Natural removal of the fallout material by wind or rain can be encouraged by utilizing details and planning devices which will make decontamination of the area easier; but they should not be expected to be completely effective. One principle to follow to make decontamination easier would be to use smooth finished materials on both vertical and horizontal surfaces. Equally important would be to avoid designs that may trap fallout in critical areas. Decontamination by hosing or sprinkling would require large quantities of water that may be in critical supply and eventually requires a system to remove the collected particles from the immediate area. Vacuuming will generally be a more effective means of decontamination but would still require disposal of the collected fallout debris.

2-4.5 Habitability

If the shelter is designed for protection against radioactivity, the period of occupancy by the shelterees may extend to many days or even weeks. In a structure not originally constructed for habitation, and yet one expected to house many people in an emergency, care must go into the planning so that modifications may be incorporated in the building hastily to permit community life to continue under emergency conditions.

The prime purpose of a shelter is to keep the occupants in good health, and therefore, almost all requirements for habitability are included for the purpose of continued good mental and physical health. Considerations must be given to the problems of food and water supply, sanitation, ventilation, heating and cooling, lighting, administration, communication, fire safety and space arrangement.

The special problems of injury resulting to personnel from a nuclear detonation may have to be treated, and, additionally the usual sicknesses, births and deaths will have to be handled. For these purposes a clinic should be considered as part of a complete shelter. The clinic would also function as the control center to maintain the good health of the majority of the occupants.

Both food and water will have to be distributed under control but only the minimum daily requirements should be planned for. Food will undoubtedly be stored at a central point and the distribution from this point would be directly to the shelterees. If any other food source is available in addition to the emergency supplies, it probably will require special preparation and eating areas. The emergency supplies alone do not require any special facilities. The water supply will also be in one central location, whether it is from a supply that has been built into the building (such as the fire fighting reservoir) or from containers especially stored for emergency use. It should be made available throughout the shelter not only for drinking but also for personal cleanliness, food preparation, cleaning utensils, removal of wastes, fire fighting and numerous other uses.

Sanitation problems involve personal hygiene of the shelterees and maintaining the environment in the best condition of cleanliness. Toilet facilities should be planned with privacy and separation of the sexes, and should be distributed for convenience to all areas of the shelter. Minimum areas must be established for commodes and washing facilities. The design and selection of materials used throughout the building should consider ease of cleaning and the control of pests.

Special attention must be given to the heating or cooling of a structure not ordinarily used for sheltering large numbers of people. Control of humidity, oxygen, carbon dioxide and odors will have to be studied for the physiological and psychological effect they might have on a confined group.

Closely related to ventilation are the space and volume requirements. Either requirement could limit the shelter capacity. Under some situations, the large volume of air of the structure will be adequate for the occupants during emergency conditions without mechanically supplied fresh air. The space available should be studied so that the most efficient arrangement can be made and the maximum number of occupants accommodated. The large flexible space of the garage should be subdivided into areas providing sleeping, eating and recreation areas for the occupants and special areas determined for the location of toilets, administration, health and storage.

In the areas established for the various functions of the shelter, the lighting should be studied. Minimum levels used in the garage structure will probably be acceptable in most areas but special or auxiliary lighting may be required in the clinic, administration and food preparation areas.

Structures used for parking garages are required by codes to have precautions for fire safety, but care should be taken to avoid the hazards that may arise if the building is converted to emergency use. Sprinkler systems and hand operated fire extinguishers are required by code to be included in certain types of garages. The shelter must still be designed to avoid fire hazards. The disposal of trash and paper should be easily accomplished and open flame devices should be avoided. Under emergency conditions, even a small fire becomes a hazard since it would consume valuable oxygen and the smoke produced could cause panic.

CHAPTER III

INCORPORATION OF PROTECTIVE FEATURES

3-1 General

In the following chapter, planning principles and construction details are analysed with respect to protection from various nuclear effects.

3-2 Site Considerations

3-2.1 Scope

The selection of a site will continue to be based primarily on economic principles for the peace time function of the proposed structure relative to the traffic pattern, parking demand and land cost. However, if the parking garage is intended to serve a dual use as a shelter, the desirability of the site as a location for a shelter should be considered. If the site has been selected prior to the decision to incorporate protective features or if the structure has already been built, certain features of the site, such as terrain or neighboring structures should be considered to determine the type of protection to be incorporated and how this protection can be best be utilized.

3-2.2 Soil Conditions

The condition of the soil is an important factor for both above and below ground structures. The characteristics and bearing capacities should be considered under both normal and blast loading. In general, it can be said that the soil conditions that behave best under conventional loading will also behave best under blast or dynamic loading with rock as the best bearing material. Under dynamic loading the structure and the soil act together which assists in resisting failure in the soil at pressures above those which would cause failure under static loads. Bearing pressures under dynamic loading are discussed in Professional Manual 100-5. In general it can be said if detailed soil information is not available, the bearing pressure may be taken as the sum of twice the conventional allowable static value plus the peak free-field soil pressure existing at the foundation level.

3-2.3 Surface and Topography

The terrain of the site and the surrounding area has some influence on the magnitude of the blast energies received on the structure. Deviations in incident overpressure are produced by the character of the surface and the topography. Declines in the ground slope in the direction of the path of the blast front cause a decrease in peak overpressure while an incline produces an increase. As the incident level of peak overpressure increases, the change in peak overpressure caused by a given change in slope becomes a smaller proportion of incident overpressure.

Fallout quantities will not be considerably affected by the terrain surface features, since the period of greatest fallout will occur after the turbulence created by the explosion has subsided. However, the earth used in grading or landscaping on the surface of an underground structure may be utilized as a barrier shield against fallout.

3-2.4 Neighboring Structures

Nearby structures could provide shielding to all nuclear effects. Non-combustible close-by structures may be regarded as a thermal shield. If they are situated on the path between the detonation and the shelter, the shelter will not be exposed to thermal radiation. However, if the structures are flammable, close proximity could present a fire hazard. Skillful building relationship could be an effective means of reducing area fires. The distance between buildings should be at least 50 feet if the probability of fire spread is to be limited to 50%, and in order to eliminate the spread of fire almost completely, the distance between buildings should be over 300 feet.

The interference of the pressure wave by a building between a shelter and the explosion is particularly noticeable in the reflected overpressures and drag loadings. If the two elements are closely spaced, the shock wave is disturbed and consequently, the drag coefficients are modified. Similarly, particularly for the shielded element, if the shock front has been substantially disturbed, reflected pressure effects may be virtually non-existent. If the distance between elements in the direction parallel to shock propagation is equal to or greater than approximately 10 times the lateral dimension of the windward element, the effects of shielding become very small and can, therefore, be neglected. In this connection it should also be noted that in open air structures the effects of shielding can usually be neglected even though the distance between individual structural elements may be much less than ten times the lateral dimension mentioned.

Neighboring buildings, if massive, will provide barrier shielding to fallout radiation.

In areas where there is a high percentage of ground coverage by buildings, the plane of contamination may be elevated and varied. This will produce a variation in the contribution at the upper level shelter areas.

3-2.5 Utilities

In order to eliminate danger from falling utility poles and to insure continued service, underground utilities are preferable. Damage to underground services beyond the ground shock area is not probable. Where the utilities pass through exterior walls, provision must be made for the relative motion between the structure and the adjacent earth in order to avoid rupture of the pipe or conduit. The possibility of loss of pressure through breakage of pipes at this point or even within the structure is more serious than failure of underground pipes. The damage to the water supply is critical for fire fighting and the problem could be partially remedied by the use of flexible connections at the building. The water supply and sewage lines should be designed so that any contaminated material cannot enter the protected installation through the piping. The emergency supplies stored in the shelter do not require the continued operation of these utilitites and completely shutting them off is an acceptable condition.

3-2.6 Landscaping

Landscaping elements in the vicinity of the shelter structure or above a belowground structure should be studied for the hazards that they may present. Trees, grass and shrubs are all subject to sustained burning and should not be located near entrances or air intakes. Decontamination of a lawn area is almost impossible unless the earth is turned over by bulldozers. It would be preferable to use paved areas that can be more easily hosed or vacuumed. Pool surfaces are self-decontaminating since the fallout material will settle and the water then provides a barrier shield. However, a pool used on the roof of an underground structure will loose the mass shielding of the water as the fallout material settles down.

3-2.7 Orientation

If the probable direction of the blast can be assumed, it should be considered in the structural orientation of the structure. General orientation of the garage should be used to resist the blast forces, since the elevation facing ground zero is subjected to the highest pressures. The effect is not very pronounced in conventional structures which are generally of a rectangular plan, but a long, narrow structure will be more resistant to blast against the end rather than on the side.

3-3 Space Requirements

3-3.1 Scope

In a garage structure, the shelter space, unlike a school or apartment building structure, is very open. The use of certain spaces for various shelter functions is not readily apparent. In a school, for example, the location of the administration would logically be assigned to the suite of school offices and the clinic would best be located in the health suite.

Space requirements and space arrangements should be studied beforehand. This can best be done by the architect when he is making his original preliminary layout of the building, and it is recommended that the architect prepare a schematic emergency-use floor plan which would be available in the garage office to assist the shelter manager. The shelter then could be quickly organized to run efficiently along the plan best suited for that particular shelter.

3-3.2 Capacity

In order to determine the necessary space assignment to each emergency function, the approximate shelter capacity must be determined. As a general rule, those floors of the structure that will be used as a fallout shelter would have an occupancy of approximately thirty times the total car capacity. This assumes that the area per vehicle is 300 square feet and also assumes that ten square feet is adequate for each shelter occupant. Both these figures should be refined by study of the various arrangements of parking and shelter facilities within the structure. The final figure will also be modified by the particular policy adopted with regard to the disposition of the automobiles during an emergency.

3-3.3 Recreation and Eating

During the period of shelter occupancy, the shelterees will be awake most of the time. Active recreation would not ordinarily be encourage since it demands more space, food and oxygen. Passive recreation is more desirable and variety can be accomplished by defining numerous small group areas. Listening to music and watching films is an excellent diversion for both children and adults. Assuming the proper equipment has been supplied, an isolated space should be assigned since the noise may be a distraction to others. Adults should have space for reading, discussions, and table games.

In most cases no special area will have to be assigned for eating space. The emergency food rations recommended to be provided for adults are a high calorie biscuit. These need no preparation and only a distribution point needs to be planned. If it is anticipated that other food sources will be available - for example, an integral type of garage shelter in a hotel could have access to the food of the hotel kitchen - then, preparation and distribution space, special eating areas and dishwashing facilities must be provided. Some area should be provided in all cases for preparation of infants food or other special diets where some cooking is required. Special areas are, however, the exception, and generally the special attention required will be limited to locating the emergency food and water distribution points. They should be both convenient to the shelterees and easy to control for the shelter management.

Under emergency conditions, seven square feet per occupant is an acceptable minimum figure for recreation and eating. Since this space would be used for two-thirds of the day, about 4.7 square feet (2/3 x 7) should be allotted for each shelter occupant.

3-3.4 Sleeping Areas

The amount of area assigned to sleeping is the most variable since it depends upon the type of beds supplied in the shelter. Probably the most economical type of sleeping accommodations to supply and store would be hammocks. These would require some fastening devices to be installed in the ceiling during constuction. If the standard army cot is to be used, a large amount of floor space would have to be assigned to sleeping. Including aisle space, an area about four feet by eight feet would be required for each bed. Assuming three shifts of sleeping, 10.7 square feet (32 x 1/3) would be required for each shelter occupant. Special bunk beds could be designed and stocked in the shelter. If a unit two feet by six and a half feet were used requiring a floor area of three feet by eight, double bunks would require four square feet per shelter occupant (1/2 x 24 x 1/3). Triple bunks could be used, but would need special design attention because of the lower ceiling heights used in garages. These would require 2.7 square feet per shelter occupant.

The location of the area assigned to sleeping should be isolated from any noisy activities.

3-3.5 Toilets and Washing Facilities

Permanent toilet installation will probably be limited to the minimum number required for the structure in its peace time function. Additional water closets in a sufficient number to accommodate all shelter occupants could not be installed without exorbitant expense. Emergency commodes included in the emergency supplies stocked within the shelter area provide the most economical solution.

Privacy is still important and advance layout and location should be studied since considerable space will be required. The number of commode locations should be far less than those required by codes for dormitory use.

The designer could assume a time-use per day and a total space assignment as a method of approximating the space required for toilet and washing facilities. For example, if thirty minutes per day per person and thirty square feet per station (including both commode and washing) were assumed, then 0.625 square feet (30/1440 x 30) would be required for each shelter occupant. If the shelter housed 1000 occupants, 625 square feet would be required. By comparison, minimum requirements by plumbing codes would require 94 water closets for 1000 persons in a dormitory structure. The space requirements would be more than tripled for this number of fixtures.

Shower facilities should not be considered because of the space and water required. A decontamination area should be planned near one entrance but even for this shower heads would be an extravagance. Decontamination by a flushing stream of water can be accomplished with a hose; or more simply, contaminated clothes can be brushed or changed before entering the shelter area.

3-3.6 Administration

By experience with shelters established during natural disasters, it has been found that proper control and administration of a shelter is the key to a successful period of occupancy. Without good shelter management, situations of near riot arise. A brief familiarity with these problems should assist the designer in making a layout that lends itself to a more efficient management. Persons taking shelter lack any preparation and few will be able to bring essential clothing or required bedding, food, water, or other supplies since the garage structure will shelter people in the city on business or shopping. The people may be in a state of exhaustion and shock. One of the first duties of the shelter management is registration of the shelterees. If the entrance is pre-disaster, registration would probably be upon entering; however, in a post-disaster situation, medical aid, food or clothing may have to be issued prior to registration. Throughout the entire emergency situation, the shelter manager is involved with accommodating the structure to the shelterees. The space use of the building must be designated; the assignment of duties to personnel for security patrol, distribution of supplies and cleaning must be made; procedures must be established concerning communications, sanitation, entertainment, religious service and many other items.

For the execution of these duties, an office should be established that has control over the shelter and yet may be physically isolated from it. Under emergency conditions, it would not seem unreasonable to provide working space of sixty square feet per worker, and that one staff member may be required in the administration office for each fifty shelter occupants. This would require a space assignment of 0.4 square feet per shelter occupant (60/50 x 1/3).

3-3.7 Health Center

In a designated shelter, medical supplies would be furnished by Civil Defense authorities prior to emergency and a proper storage point should be established. Closely related to this in the plan layout should be the location of the proposed health center. In previous emergency conditions, shelter problems have almost overwhelmed the medical staff as most people were not in the shelter at the time of disaster. This may or may not be the case in the event of a nuclear attack.

If the occupants enter the shelter after a disaster, medical treatment will be an important function of the shelter. If the occupants enter prior to an emergency, a medical center will be required for the period of occupancy to assist the infirm, and aged, as well as to control the spread of communicable diseases. Ward space will not require additional space as it can be taken from the dormitory and recreation space allowance.

3-3.8 Storage

A complete description of the materials recommended to be stored in a fallout shelter is described in OCD Manual 8520.1. Briefly the following kits are available and selected ones probably will be used in the shelter:

Kit	Volume	Persons to be supplied
Sanitation Kit III	3.36 cu. feet	25
Sanitation Kit IV	3.36 cu. feet	50
Radiation Kit	1.08 cu. feet	One per shelter
Food	2.26 cu. feet	7
Food	1.52 cu. feet	5
Medical A	1.0 cu. feet	65
Medical C	5.2 cu. feet	325
Water	17.5 gallons	5

In a garage shelter, these supplies would take about 0.16 square feet per shelter occupant. Other supplies may be required, but are not as yet available in OCD prepackaged storage kits. Consideration should also be given to storage of beds, bedding, furniture, amusement articles, etc.

3-3.9 Summary

The total net area per shelter occupant including space for recreation, eating, toilets, administration, medical and storage, but excluding sleeping space is about six and a half square feet. The space requirements vary chiefly with the sleeping arrangement proposed. If cots are used for sleeping, 17.2 square feet is required, if double bunks are used 10.5 square feet, and if triple bunks are used, 9.2 square feet are required. These net areas should be further increased to 23, 14, and 12.5 square feet to allow for circulation space.

Finally, of course, these figures only apply to free area not occupied by automobiles. The policy of evacuating automobiles from the shelter will vary with the structure and the particular situation. The occupancy rate of parking garages vary from nearly empty to, in some cases, over 100%. The average occupancy could be assumed to be 60%.

3-4 Special Considerations of the Automobile

3-4.1 Scope

The planning of a shelter structure designed to protect people from the effects of a nuclear detonation that has a primary function as a parking garage should necessarily consider the possible presence of automobiles in an emergency. As pointed out previously, the automobile presents some indirect hazards to the shelterees from the blast and thermal energies. There are other disadvantages and problems presented by the automobile which should be considered. Additionally, there are some features which may be regarded as assets and some study can take advantage of the presence of automobiles.

3-4.2 Space

The two major limiting factors to the number of occupants which may be housed in a shelter are floor space and volume. Though the floor space and volume taken up by automobiles remaining in the shelter is difficult to use, it is not necessarily lost. The interior space and the volume above and including the vehicle could be counted as part of the volume of the shelter.

Warning time would, of course, determine when the automobiles may be evacuated relative to an attack. A preattack evacuation is desirable for the most efficient use of the shelter. If the situation permits the garage should be closed well in advance of a possible emergency. No problem of car removal would arise and a maximum amount of space would be available.

In the event that evacuation is not possible prior to an attack, the automobile may or may not be removed during the crisis. It should be noted that even if the garage is filled to its maximum capacity of automobiles, as much as half of its floor area is open to use by shelterees and space is still available in the interiors of the vehicles. Without attempting to remove the cars completely from the shelter, the space can be rearranged into more usable areas. The vehicles could be pushed into areas of lower protection factors where their mass could provide additional shielding or they could be concentrated in a single area and assigned as sleeping areas.

If it is decided to remove the stored vehicles from the shelter in a post attack evacuation, it will be difficult except in the case of above ground shelter. If the shelter is below ground, pushing many cars manually up a 15% grade would be very taxing on the shelterees. On the other hand driving them out would overtax the mechanical ventilation system to exhaust the carbon monoxide.

In either case the vehicles would have to be removed in the short period before fallout dust begins to settle or after the radiation intensity falls low enough to permit short periods of stay in unprotected areas. In high building density areas there would be little or no space for autos without blocking critical traffic routes.

3-4.3 Supplies

Whether or not the automobile remains or is removed from the shelter, certain items within them could be used from them that may be useful in an emergency. The presence of the automobiles should be relied on in planning for the efficient operation of the shelter since it would still be preferable to have the automobile evacuated prior to occupancy, and the materials available from the automobile would not be accessible. If the vehicles are in the structure some items undoubtedly can be used to relax demands on the emergency supplies.

Water is the most useful commodity that must be supplied and it is doubtful if too much could be stored in a shelter. Needed critically for drinking, the water stored in the emergency supply kits would not be available for washing or cleaning. The water in automobiles, even though containing antifreeze and not potable, could undoubtedly be utilized. Improvising storage facilities for the water would be difficult. Vinyl sheets should be stored for possible use as tank liners.

If a gasoline power generator is part of the mechanical equipment, the gasoline from the tanks of the stored vehicles could serve as a reserve fuel supply for the emergency power requirements. Removing the gasoline from the tanks and handling would have to be carefully controlled because of the explosive vapors involved. Storage tanks would probably not be available to contain the gasoline and planning to remove the fuel prior to evacuating the vehicles from the garage does not seem probable.

Numerous other items should be considered as possible useful materials in an emergency. Batteries could be removed and combined as an emergency power source for lighting and communication equipment. Car radios could be place throughout the shelter to be used as an intercom system. In some cases removed short wave sets may be used for communications to Civil Defense headquarters.

If the vehicle is to be taken from the structure, the seats should be removed to serve as seating in the shelter. Other helpful items such as tools, flashlights and blankets should be stored in the shelter before the automobile is removed.

3-5 Structure and Materials

3-5.1 Scope

The selection of the structural system and the materials of construction in relation to the function to be housed within a structure, the location of the structure (i.e., aboveground, belowground, or partially buried), the desired spans, the exterior walls (i.e., completely open, partially open, frangible or non-frangible), etc., is an important planning consideration in conventional building design. This selection becomes even more important for a structure designed to resist low level blast pressures and to provide nuclear radiation protection. Therefore, increased attention to these considerations is required in the structural planning and design of such protective structures.

3-5.2 Type of Structure

Parking garages situated above-ground are of two general types: enclosed and open air, or possible a combination of the two types. Although the most common type for commercial garages is the open air, the reaction or response to nuclear blast effects and the nuclear radiation protection capability of both types will be discussed. Appendix A, "Weapons Effects," contains a general discussion of the propagation of blast waves and their interaction with structures.

a. Above ground enclosed

A structure with wall openings, i.e., doors and windows, with an area of less than about 5 per cent of the total exterior wall area, is considered to be an enclosed structure for purposes of determining the blast loading on the structural system, i.e., the exterior walls, roof, supporting frame, shear walls, foundations, etc. It is further assumed that the walls are sufficiently strong so as to remain intact under the blast loading. The pressures on the interior surfaces of the exterior envelopes and the supporting frames are assumed to remain at the ambient pressure level before the arrival of the shock front of the blast wave, i.e., the inside overpressure is zero.

As the shock front strikes the structure, it is reflected and the pressure in the wave is substantially increased above the peak overpressure of the blast wave. The resulting reflected pressure which is the loading on the front face of the structure is not only a function of the peak overpressure of the blast wave before reflection, but also of the shape of the structure (i.e., rectangular, arched, etc.,) and of the angle of incidence between the shock front and the structure. For a rectangular structure with a wall directly facing the shock front, this "front face" is loaded by a "reflected pressure spike." As the shock front passes over the structure the reflected pressure rapidly decays. The duration of the reflected pressure is a function of the initial peak pressure and the dimensions of the loaded front face. The front face loading is subsequently caused by the ambient overpressure (similar to a hydrostatic pressure) of the blast wave and by the dynamic pressure of the blast wave due to the translational movement of the air within the blast wave (similar to the drag loading of wind forces).

As the shock front passes over the structure, the roof and side wall surfaces are progressively loaded until the shock front reaches the back face of the structure at which time roof and sidewalls are fully loaded. The back face is not loaded until the shock front reaches the back of the structure, and the loading is progressively built up as the shock front spills over from the roof and around from the side walls. The roof, sidewall and back face loadings are functions of the overpressure and the dynamic pressure existing within the blast wave. Whereas the dynamic pressure increases the loading on the front face, the dynamic pressure serves to decrease the loading on the roof, side walls and back face.

These previously described loads are those to which the exterior walls and roof surfaces are subjected and for which they must be designed. The structural elements supporting these surfaces must in turn be designed for the reactions of the exterior elements. However, these reactions will not equal the loading on the exterior surfaces because of the dynamic nature of the loading and response of the exterior surfaces. In the design of any supporting system, the net horizontal loading, i.e., the front face loading minus the back face loading, must also be considered. After the back face has been loaded, the overpressure components of the loadings on the front and back face are essentially that caused by the dynamic pressure, i.e., the drag force loading.

Therefore, the loading on an above ground enclosed structure is dependent on the areas of the exposed exterior surfaces, the overpressures, and the associated dynamic pressure. Inasmuch as these exterior surfaces of a garage would be rather large in area, the exterior walls and supporting frame system would be required to carry rather heavy loadings.

b. Above ground Open Frame Structure

At the opposite end of the spectrum from the totally enclosed structures is the open frame structure without any wall covering, or with light, frangible walls (e.g., glass, asbestos, light steel, or aluminum panels) which shatter on impact and transmit only a small or negligible load to the supporting frame. In such a frame structure, only the individual small structural elements of the frame are subjected to the blast wave.

For both the framing elements and the slabs (roof and floor), the overpressure is essentially balanced on all sides, and the primary loading on the structural members of an open frame structure, therefore, consists of the drag loading resulting from the dynamic pressure of the blast wave. Furthermore, depending on the relative size and spacing of the individual elements, e.g., columns, bracing, etc., the various members tend to shield each other to some extent from the full effects of the blast wave, and thus reduce the loading.

Therefore, the loading on the elements of an open frame structure is dependent on the area of the exposed members and the dynamic pressure. Since the area of the exposed elements of an open frame structure is only a small percentage of the exposed wall area of an enclosed building, and since the dynamic pressure is relatively small compared to the overpressure of the blast wave, the loading on an open frame structure is much less than for the enclosed structure. However, the increased mass and strength of the latter partially compensate for the increased load.

c. Underground Structure

A below-ground garage would either be located under an open area, e.g., a plaza or park, or in the basement area of an above-ground garage or other building. The only significant difference in the loading would be that on the roof slab, whereas the side walls and floor slab would be subjected to the same type of loadings in both cases.

A below-ground garage under an open area would generally have a maximum earth cover of only a few feet which would be insufficient to develop arching action and for any significant attenuation of the pressure to occur. With the roof slab flush with the ground surface or having only a few feet of earth cover, the roof slab is subjected essentially to the overpressure of the blast wave, without any contribution from a reflected pressure spike or from the dynamic pressure.

If a building is situated above the below-ground garage, the roof slab loading on the garage is dependent on whether the building is enclosed or open air. If the building is completely enclosed, the loading on the garage roof slab is zero, whereas if the building is open, the roof slab loading would be essentially that of the blast wave overpressure.

Inasmuch as the loading on the sidewalls of a below-ground structure is dependent on the coupling between the soil and the structural element itself, the wall loadings will be a function of the physical properties of the soil (e.g., soil type, density, degree of compaction, placement procedure, etc.) and the mass and stiffness of the walls. If the side walls are fairly stiff, the lateral loadings are increased; however, if the sidewalls are relatively flexible, the loadings are decreased. The soil-structure interaction problem is very complex and generalities are extremely difficult and dangerous to make. The supporting structural system is, of course, in turn loaded by the reactions of the side walls as they respond to their loadings. Depending upon the pressure level, the structure might also be subjected to an overall acceleration, i.e., gross body motion.

A partially buried garage structure will be subjected to loadings similar to that of an enclosed above-ground garage structure, except for those portions of the sidewalls below grade-line. If the cover is mounded around the portions of the sidewalls above the grade line, the resulting aerodynamic shape is improved resulting in decreased drag loadings on these upper portions of the sidewalls. In addition, the increased mass of the earth cover most probably would decrease the response of the sidewalls.

3-5.3 Structural Layout

The general structural layout of a garage is based on the parking requirements of the automobiles or a projection of the structural grid of the superstructure when another function is housed therein.

In a rectangular structure, shear walls are generally superior in performance to rigid frames and may be less expensive. However, large openings required to facilitate car movements are of such a size that they would greatly reduce the effectiveness of shear walls. Shear walls could be used in those area around the entrances and other facilities where open space is not demanded.

Arches and domes are superior structural shapes because of their inherent structural strength and their better aerodynamic characteristics resulting in reduced structural loadings. However, it is generally inadvisable to use them to house parking garages as the volume created cannot be fully utilized and their constructions cost higher.

Either flat slab or T-beam construction may be used, but in a structure used as a parking garage the economy of headroom requirements makes the flat slab more desirable.

Long spans should be eliminated wherever possible in order to reduce the size of the roof slab.

3-5.4 Blast Resistant Design Considerations

In blast resistant design there are three considerations which are significantly different than the commonly accepted design procedures of structures designed for conventional loads. (1) The increased loading rates of structural materials under the dynamic loads experienced in blast resistant design generally result in increased material strengths, particularly in yield of steel. (2) The inertia forces tend to reduce the resistance required of a structure and/or structural element to withstand a given level of load. (3) Structures have a large reservoir of load-carrying capabilities beyond yield when they are designed to be ductile, i.e., capable of deflecting within the plastic range of behavior.

Blast resistant procedures generally recognize all three of these considerations. Preliminary design can be based on static resistance equal to the peak applied force using static yield resistances. However, the final design should be in accordance with blast resistant procedures in order to insure that the response is acceptable.

3-6 Openings, Entrances and Ramps

3-6.1 Scope

Openings and entrances are particularly critical elements in parking structures designed to resist nuclear blast effects and to provide protection from nuclear radiation. The ventilation, pedestrian, and large vehicular openings in an enclosed parking garage require special attention. Inasmuch as blast pressures on the order of 5 psi can cause rupture of eardrums and seriously damage vehicles, interior partitions and furnishings, it is desirable to completely exclude the blast wave. For ventilation systems, either a manual or an automatic blast closure devices is satisfactory. The large openings must be securely and positively closed prior to the arrival of the blast wave and automatic actuation is not rapid enough to close the door prior to the arrival of the blast wave. Filtration of the incoming air after an attack would in general be required.

3-6.2 Blast Effects

When an air blast enters a tunneled entrance or an air duct, a new wave front is generally formed inside the tunnel and the shock propogates itself through the entrance or duct. Considerable research effort has been expended on the problem of the entry of shock waves into tunnels and the subsequent behavior of these waves in various tunnel configurations. Because of the tremendous energy and the long durations of blast waves resulting from nuclear explosions, the lengths and/or configurations of parking garage entrances are not sufficient to provide other than a very minor attenuation of the pressures in the blast wave. Baffles and tortuous paths, although effective for reducing pressures from conventional high explosive detonations, are very ineffective in reducing blast pressures from a nuclear explosion. Therefore, a positive closure of these large openings is required to exclude the blast pressures.

A through-ramp entrance, either open or covered, which can be entered from either end with the closure offset in a leg at right angles has definite advantage. There are no reflecting surfaces and the door is subjected essentially to overpressure.

For a non-through ramp entrance, a roofless ramp is best. However, if a covered ramp is required and turns are permissible, the pressure will be significantly reduced if the closure door is placed along the sidewall rather than in the end wall.

3-6.3 Radiation Shielding

Entranceways should be shielded in such a manner that the contribution through the entranceway is minimized. Baffles, either interior or exterior, and right angle turns are quite effective in reducing the contribution through entranceways. Closed or covered entrance ramps are to be preferred in that they not only provide additional attenuating mass, but they also remove a contaminating plane from being immediately adjacent to the structure and provide a "tunnel" which further decreases the contribution received within the garage from other sources.

In order to minimize the fallout drifting down the ramp and lying against the structure and possible door, pits with open grills in the ramp floor are recommended to trap the contamination.

3-6.4 Entrance Doors

Incorporating effective barriers to the blast front at the large vehicle openings is one of the main structural, architectural and mechanical problems of a parking garage which is to serve as a blast shelter. The major expense and intricate detailing involved in providing a massive operating door that will remain operable is probably the critical design item in this type of blast shelter. Because of the expense of blast doors, they may be omitted from the initial construction but the designer should plan the entrance closure details in advance.

Horizontal blast doors which would only be subjected to side-on overpressures may be used for the small openings normally used by pedestrians entering and leaving the structures.

Vertical doors located so they are not subjected to reflected pressures should probably be installed in the vehicle entrances since the openings are smaller vertically than horizontally for ramped entrances. The designer should also consider installing separate doors for each lane of traffic in order to reduce the size of the door to be operated.

Large doors may be either hinged or sliding and there are advantages and disadvantages to each. A top hinged door to gain maximum support against the positive blast phase would swing out and the structure may be used to resist movement of the door. The negative phase, assumed to assert a force equal to fifty per cent of the positive pressure in the opposite direction, must be resisted by a series of bolts or pins. The problem of simpler support system for an outswinging door must be balanced against the problems of opening the shelter door into the direction of traffic under emergency conditions. Horizontal sliding doors operate slower and require more energy to close than vertical sliding doors. As in the case of hinged doors, resistance to one phase of pressure can be obtained from the structure while some device must be installed for the opposing action. A door stored in a recess presents the special problem of maintenance in an inaccessible area.

Exposed parts of the door mechanism may be damaged by heat, fragments, rubble and dust. When the site or neighboring structures places the door in a vulnerable situation, it is preferable to locate the closure within the protected area of the shelter. In addition to direct weapon effects, the operating mechanism may be subject to very large forces transmitted from the door. The door mechanism should be isolated from these forces by supporting the door independent of the rollers or other elements of the door mechanism.

Operation of the door will require a power source. Small doors may be operated by hand or an integral power source such as compressed springs, explosive cartridge or power cylinder, but large doors may require large power source for a short period of time. An emergency power source should be provided such as counterweighing, hydraulic-pneumatic or standby generators.

3-6.5 Ventilation Openings

Large shelters require a forced ventilation system consisting of air intake and exhaust passages and the means to circulate air. A blast valve or other mechanism restricting the flow of blast through these air passages is desirable. Manually operated air handling units are generally impractical because of the volume of air to be changed and the corresponding static air pressures required. In addition, quantities of air for cooling and for combustion will be required for the gasoline or diesel engine driven generators (wherever used).

The size of the ducts required to provide a minimum acceptable air flow will be reasonably small. These ducts may be incorporated as part of the entrance system, in which case, additional fallout baffling is minimized. Alternatively, the ducts may lead directly from the shelter to intakes on the ground surface. In this case, sufficient bends or baffling must be provided to eliminate direct penetration of radiation. In addition, a small structure on the ground surface would be required to protect the entrance from debris and snow. It is recommended that blast valves be located on the interior ends of these ducts so that the valves are convenient for maintenance during an emergency. Blast valves to close the passage to blast pressures may be operated remotely by blast, light or radiation sensors and auxiliary power sources or by the blast itself.

The volume of air required at the emergency generators may be larger than that required for the sheltered personnel. Although locating the generators within the shelter area makes it accessible for maintenance, the increased cost of installing a protective supply and exhaust duct may be prohibitive. It is usually better to locate the generators outside, but convenient to the shelter. In an outside area, normal air circulation will provide sufficient cooling and combustion air. Standard engine generators can be modified to withstand low level blast pressures, but should be shielded against radiation contamination as much as possible to allow for maintenance.

3-7 Mechanical and Electrical Equipment

3-7.1 General

A closed parking garage is notable both as a massive structural building as well as having an extensive ventilating system. On the other hand, an open-air parking garage is notable for the lack of enclosing walls and for the lack of any mechanical ventilating or heating system. Depending upon height and size, either type of garage might be equipped with an automatic sprinkler system, but probably would not be equipped with extensive water supply or sanitary facilities. Lighting levels are generally very low in all garages.

3-7.2 Effect of Large Volume

It is probably a unique characteristic of a parking garage that there is a large unobstructed air volume compared to most spaces available as fallout shelters. There are very few intermediate partitions or closed-off spaces. Due to the inter-connecting ramps and the large parking and turn around areas, there will probably be large open spaces available for occupancy even though the garage may have a large number of autos at the time of usage. And, of course, the spaces within and on top of the autos may be used even if autos are occupying the garage. Consequently, the free volume per occupant will probably be sufficiently large to control carbon dioxide concentration and to insure sufficient oxygen content for extended periods without mechanical ventilation. An open-air garage would have to be closed with tarpaulins (or other type of screening) to prevent dust penetration, but would allow some infiltration air depending upon wind direction and magnitude. Infiltration would be undesirable during periods of high concentrations of radioactive dust in the atmosphere, but after this period would be of some advantage in providing ventilation to prevent heat and moisture build-up within the occupied space.

3-7.3 <u>Supply and Exhaust Fan and Filter Room</u>

The supply fan and filter must be installed in a separately enclosed and shielded room. The fan system should be provided with a bypass that can be used during emergencies to filter the smaller dust particles in a more efficient manner than would be required for the normal use of the building. Consequently, the main fan must either be so selected that the reduced air quantities with higher filter resistances will still be sufficient for the use of the space, or a separate booster fan must be combined with the more resistive filters so that this additional resistance is not imposed on the main circulating fan. Spare filters must be stored in an accessible and clean area so that they may replace the primary filters in case the first set is damaged during the initial stages of a nuclear attack. There should be at least two extra sets of filters to account for possible subsequent blast damage. The air intake should be shielded so as to prevent direct wind pressure from forcing excessive dust quantities into the opening, and the air intake should be turned down so that the air must rise up into the opening and, therefore, leave the larger and heavier particles of dust on the outside. If blast is to be a consideration, some form of blast valve should be considered and some form of expansion chamber inside the ventilating air inlet should be provided to assist in reducing the overpressure at the filter and at the supply fan.

3-7.4 <u>Emergency Power</u>

A typical commercial garage would not have emergency power available and would not normally have heating or cooling equipment of any magnitude. Emergency power could be provided by a small gasoline or diesel engine-driven generator. Although gasoline storage poses some problems in deterioration, a gasoline engine generator is less expensive and somewhat easier to start than a diesel generator. In addition, most people are somewhat familiar with gasoline engines and a mechanic is likely to be available among the occupants in case of emergency. Spare parts may probably be found among the many automobiles; and extra gasoline could be obtained from the parked automobiles, if necessary. The only emergency power requirement would be the central supply fan and the building lighting. The building exhaust system would not be operated in order to allow the building supply system to maintain a positive air pressure within the building to assist in excluding dusty infiltration air, and other contaminates.

The emergency generator should be located reasonably close to the supply air fan since this is the major load that it would serve. The main building lighting panel should also be located as close as possible. The emergency generator should preferably be in a protected and non-contaminated area and should have sufficient air supply to satisfy its cooling needs. This may be accomplished by exhaust air from the building. If this is not possible, the use of a separate chamber for the air cooled radiator separately located from the generator should be considered so that the generator and its maintenance personnel would not be contaminated by the large quantities of air required by the radiator to cool the water for the generator. This water, of course, would have to contain anti-freeze to insure operations during freezing weather. The gasoline or diesel engine fuel supply must be located nearby and in a protected enclosure to insure that initial radiation or subsequent blast does not damage the fuel supply system. Generally speaking, this would imply that the fuel supply should be on the lower floor or below ground and the electrical generator would, therefore, be somewhere in this vicinity. It is possible, of course, to supply the fuel by pump to higher levels; but this not only consumes electrical power, it also imposes another possibility for mechanical failure.

3-7.5 Water for Human Consumption

Fresh drinking water would not normally be available in any large quantity except on the ground floor level, and only if the garage contained public eating and lobby facilities. Therefore, emergency water supplies would be required to be stored either in emergency containers on each floor or in some central emergency water storage tank facility. If the building contained a sprinkler system, it could be used as an emergency source of supply. It would probably be of the dry-pipe type since the building is generally unheated. However, a house storage tank of water on the top floor, or in a penthouse on the roof, would insure a minimum supply of water for the sprinkler system without relying on electrical motor driven pumps which could fail in case of emergency. Under these conditions, water could be made available on each floor through a simple emergency hose bibb arrangement. The house storage tank must be normally heated to prevent freezing.

3-7.6 Water for Waste Disposal

A typical garage will not have toilet facilities on each floor; however, emergency containers and chemical toilets could be provided for emergency use. The automobiles will contain large quantities of water in their radiators, if there are automobiles in the garage at the time of occupancy. This water can be used for basic washing and cleansing purposes, and for general decontaminating purposes, even if it is not fit for human consumption (because of anti-freeze).

3-7.7 Normal Lighting

The lighting levels in a parking garage are usually of such low level that the entire building lighting system could probably be put on the emergency generator system. The one exception would be advertising signs using large quantities of electrical current. Other than the lighting, the only other major electrical load in a parking garage would be the elevators in a multi-story garage. During an emergency, these could be shut off so as not to impose their load on the emergency generator. Therefore, the emergency generator would only serve the supply fan and the minimum building lighting system.

3-7.8 Emergency Lighting

An emergency lighting system could be provided in addition to the normal lighting system. The emergency system could be designed for 6 and/or 12 volt power supply. This would allow for the emergency use of batteries in the automobiles as required (and if available). On the other hand, if automobiles are available, the headlights and taillights are probably sufficient for emergency use.

3-7.9 Fire Storm

In case of a fire storm, the fresh air ventilating system would have to be turned off temporarily to guard against entry of abnoxious and dangerous fumes, smoke, and carbon monoxide. The fresh air intake should be properly located and designed with this in mind. However, the open volume of the interior spaces should be quite sufficient to maintain livability for a period of a few days without a forced air supply ventilation system because of the large volume of the space. The space would become warm and humid due to human occupancy, but the mass of the building would absorb some of this and the rate of temperature rise would be reasonably slow. Naturally, an underground space would be better suited as a shelter in an area of fire storm; however, there is no reason to believe that a windowless type of building such as a garage would not endure through a fire storm without collapse and with reasonable safety for the occupants assuming that other openings such as major doors and ramps could be provided with some type of closure.

CHAPTER IV

DESIGN EXAMPLES

4-1 General

The following examples are included to show various design solutions of parking garages which incorporate some degree of protection. As well as illustrating various garage types and ramping systems, comment is made on the probable location of the type. For shelter purposes, the structures are reviewed for special thermal and structural resistance incorporated in the design. The plans are criticized for the adaptability as shelter area in a period of radioactive fallout.

4-2 Open Air Type
(Example A)

4-2.1 Architectural Description

This design, representative of the most common type of commercial parking garage, is usually constructed by private interests in the center of large cities or is built by the municipality and leased to another party for administration.

A ramped system is used for vertical circulation in the eight story fireproof structure illustrated. It is assumed to be an attendant operated garage where the first floor is devoted to customer facilities. The structural system is reinforced concrete and a bay size of 28' x 24' was selected to accommodate

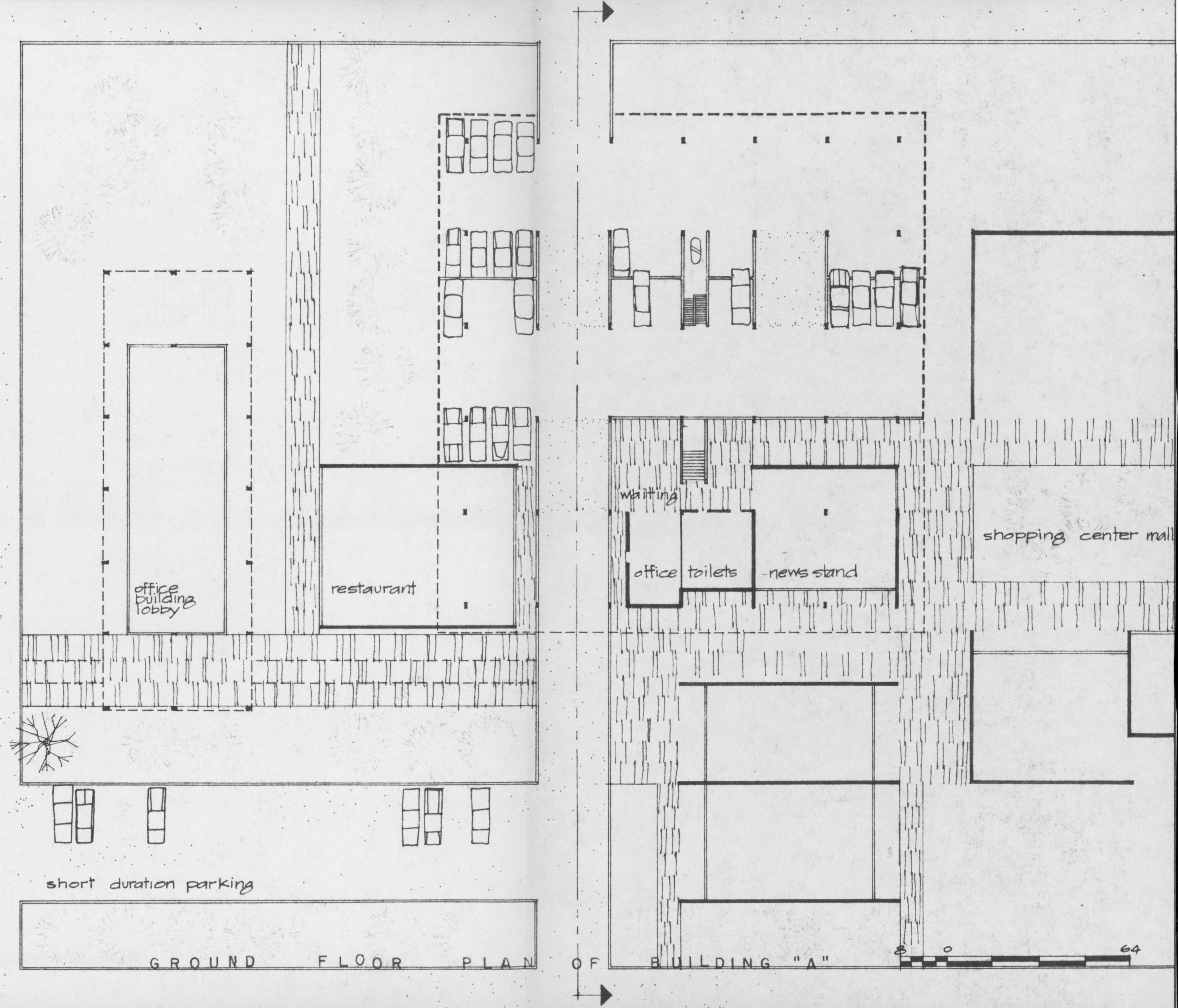


FIGURE 4-1 GROUND FLOOR PLAN OF BUILDING "A"

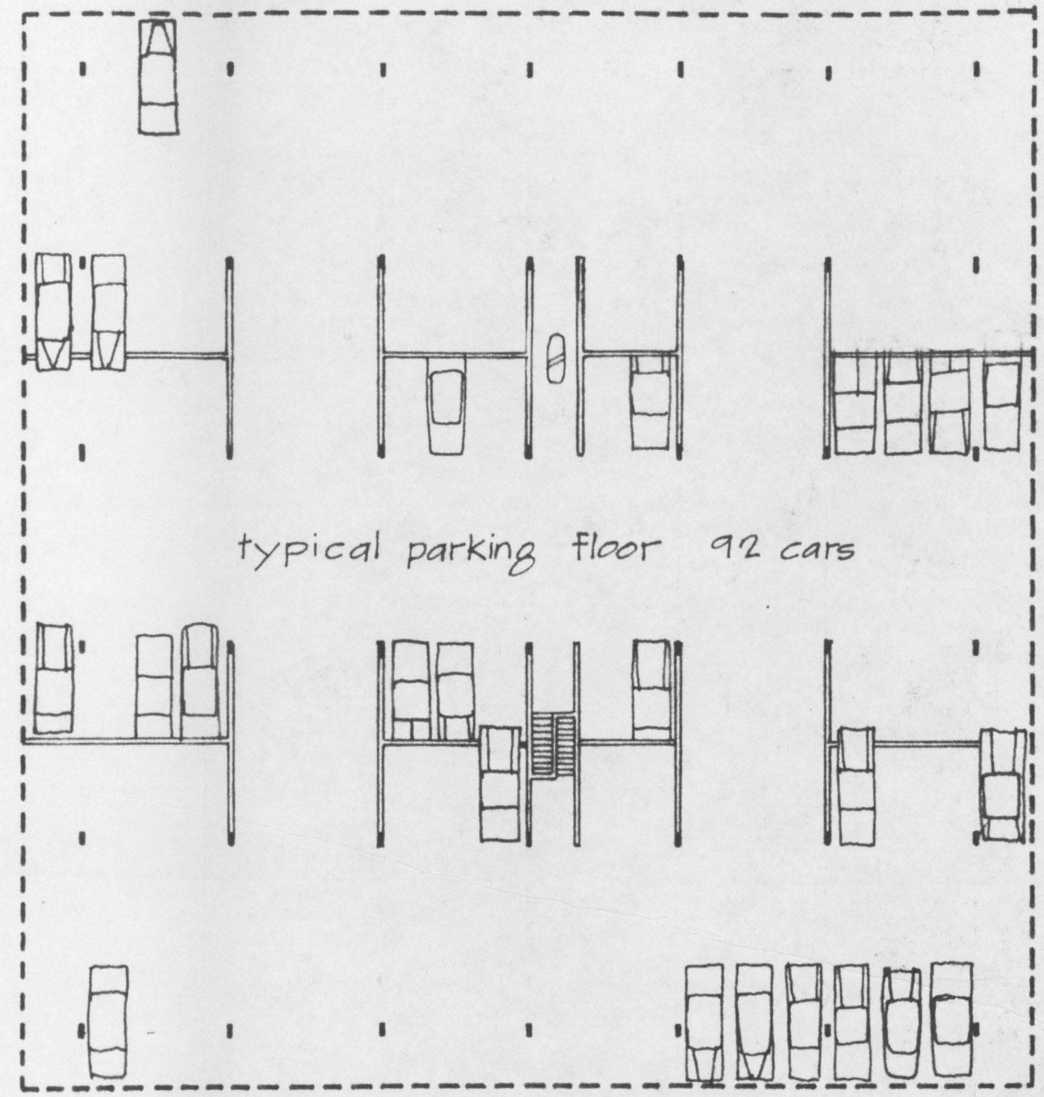
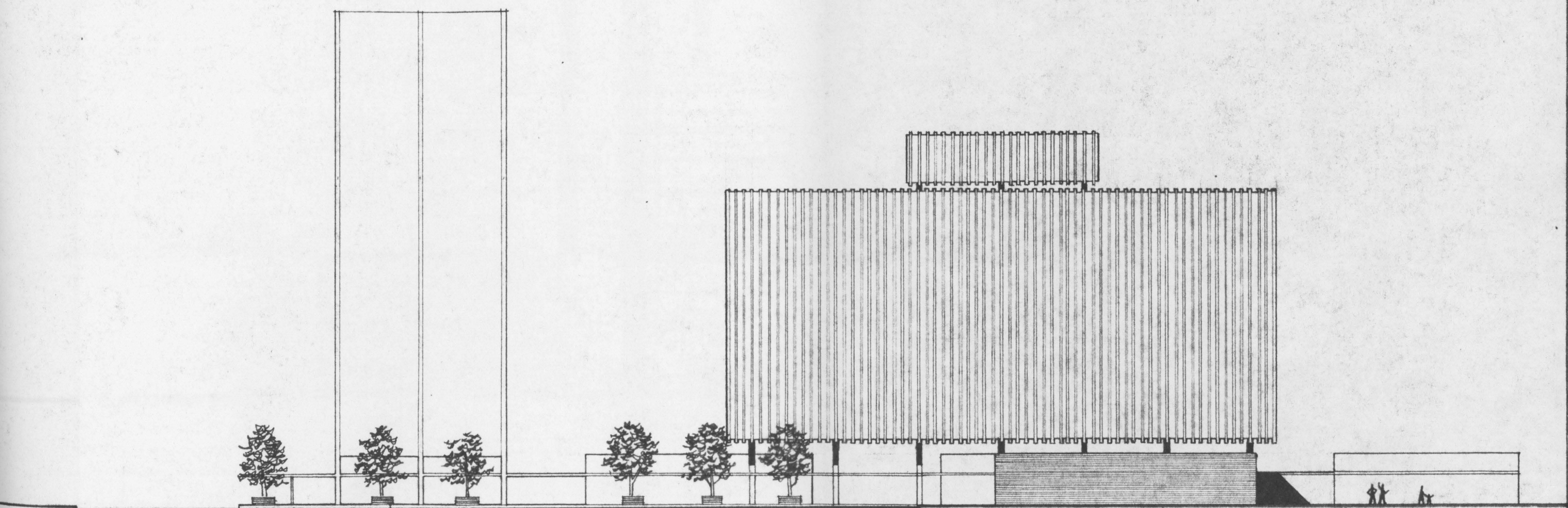
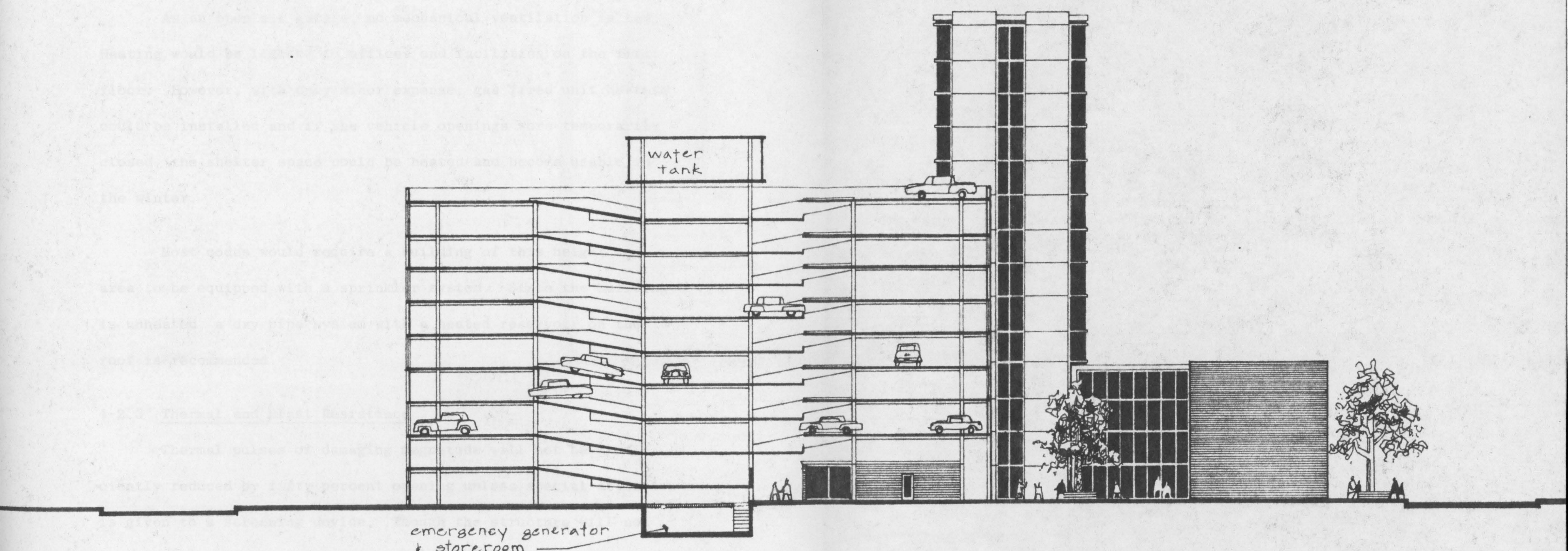


FIGURE 4-2 TYPICAL FLOOR PLAN OF BUILDING "A"



IGURE 4-3 ELEVATION OF BUILDING "A"



GURE 4-4 SECTION OF BUILDING "A"

0 64

three cars per bay.

4-2.2 Mechanical System

As an open air garage, no mechanical ventilation is required. Heating would be limited to offices and facilities on the first floor. However, with only minor expense, gas fired unit heaters could be installed and if the vehicle openings were temporarily closed, the shelter space could be heated and become usable in the winter.

Most codes would require a building of this height and area to be equipped with a sprinkler system. Since the building is unheated, a dry pipe system with a heated reservoir on the roof is recommended.

4-2.3 Thermal and Blast Resistance

Thermal pulses of damaging magnitude will not be sufficiently reduced by fifty percent opening unless special attention is given to a screening device. Though the structure will not burn, a fire hazard exists since the automobiles may ignite.

As an open air building, the structure exposes a minimum area to the blast forces and the structure itself is, therefore, less vulnerable to blast pressures than an enclosed structure. To further minimize the impulsive loading that may be transmitted to the frame, frangible siding could be installed. It is not practical to modify this structure to protect occupants from blast pressures.

4-2.4 Shelter Considerations

This type of garage could serve best as a shelter to fallout since the design will not permit building-up a positive pressure to exclude bacteriological or chemical warfare products. In order to use the structure as a fallout shelter, temporary closing methods such as the installation of vinyl sheets over the openings must be used to prevent drifting of fallout material into shelter designated areas. Any closing method used must necessarily be installed after the blast pressure period since these areas would be vulnerable to blast pressure. If some contaminated material entered the structure before closing, the sprinkler system could be used as a method of decontamination.

Assuming no mutual shielding from neighboring structures, no contamination within the structure from drifting, and a negligible mass thickness for the exterior walls, the interior bay of the garage shown has protection factors above forty for all floors except the ground floor. The third to seventh floors has protection factors in excess of one hundred in the central bay and in excess of forty in the two adjacent interior bays. A structure of the same general dimensions and capacity but without the staggered floor system of ramping would not provide a shelter area in the center bay with a protection factor as high as one hundred. Ideally the automobiles in the structure should be moved to those areas on the perimeter where protection factors are low. Doing this would free more area for shelter purposes and provide some additional mass shielding in more exposed areas.

An emergency stand-by generator located in a pit below the central aisle is suggested to provide electric power for lighting during an emergency. Emergency supplies could be stored in an underground storage room opening off the generator pit. Both the equipment and storage areas could be located in the half story space under the center slab if the design is not concerned with blast pressures.

4-3 Underground Type
(Example B)

4-3.1 Architectural Description

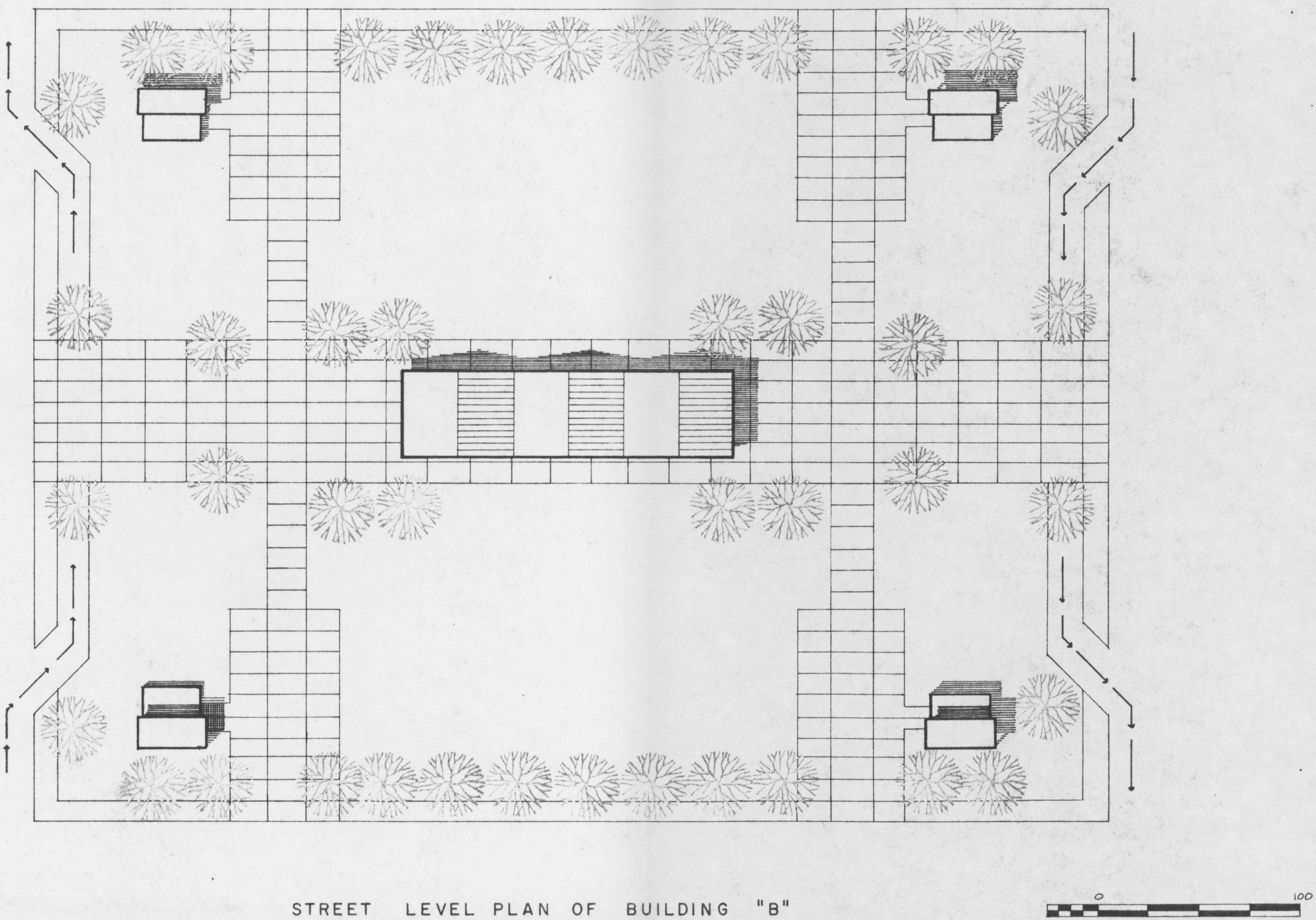
The underground type illustrated is typical of the numerous facilities included in major central business district projects or in urban renewal areas where an attempt is made to conceal automobile parking. The area above the garage is an open paved piazza which would enhance the downtown area. If the garage were in an urban renewal area, the park-like green space could serve as a recreation area for the neighborhood.

In the scheme illustrated, it assumed that the customer pays a fee but parks his own vehicle. In projects of this type the number of floors may be limited by problems of excavation, but three floors are shown in this solution.

Because customer parking is used, the structural bay size is increased above minimum standards to a 28' x 26' bay allowing slightly more space to maneuver the vehicles.

4-3.2 Mechanical System

As an underground structure is completely enclosed, mechanical forced ventilation is used throughout the entire structure. Heating, however, is limited to the control areas near the vehicle entrances.



GURE 4-5 STREET LEVEL PLAN OF BUILDING "B"

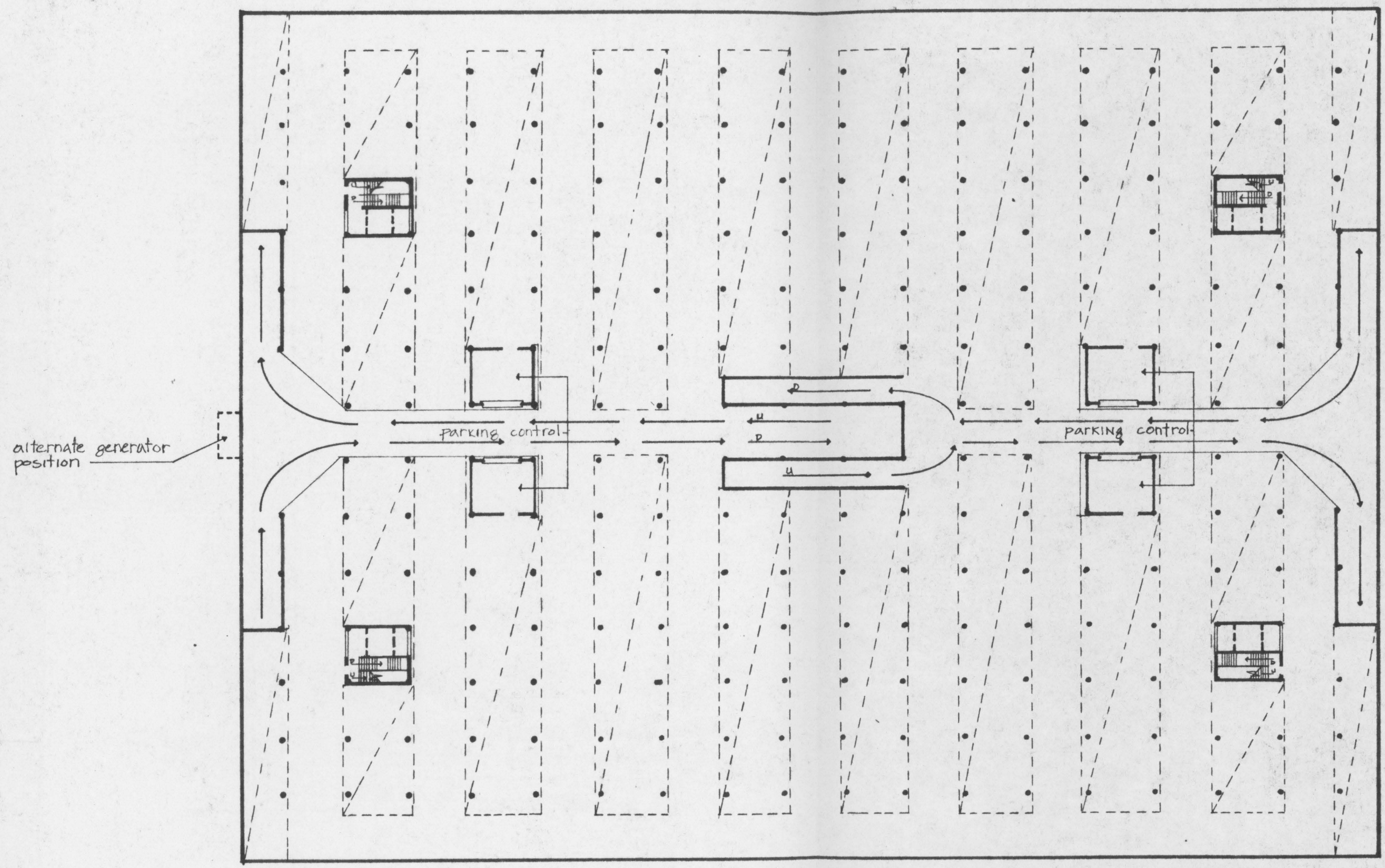
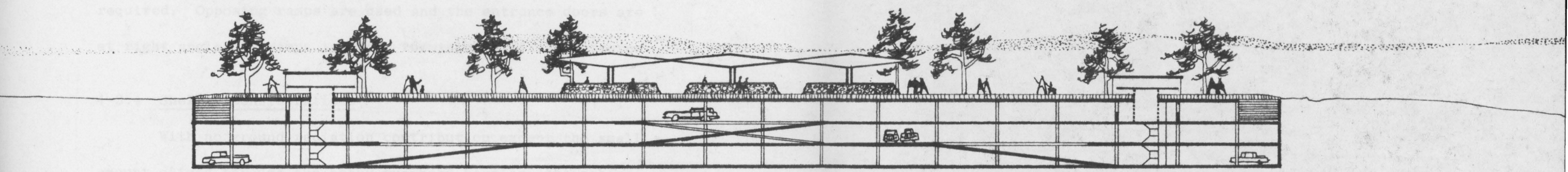


FIGURE 4-6 FIRST BASEMENT LEVEL PLAN OF BUILDING "B"



URE 4-7 SECTION OF BUILDING "B"

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The fresh air intakes are housed in the structures over the four pedestrian entrances. Fan rooms are located in the first level below grade. One of these fan rooms could also house a generator for emergency use.

In this design it is assumed that the sprinkler system is a wet pipe system fed by the city supply.

4-3.3 Thermal and Blast Resistance

Since the structure is underground, the effects of thermal radiations will be negligible on the structure, vehicles and personnel. Blast effects on the structure are minimized and protection of personnel can be accomplished by some modification.

Blast closures at the openings are the major modifications required by this structure. Commercially developed devices are available for passage doors and openings for the mechanical equipment, but at the vehicle openings massive doors will be required. Opposing ramps are used and the entrance doors are at right angles to ramps in order to minimize blast pressures.

4-3.4 Shelter Considerations

With no ground radiation contribution except the small amount gained through the heavy overhead barrier, the scheme represents an almost ideal solution to shielding from nuclear radiation. Again, the major shielding problem involves the large openings of the ramp. Assuming no contamination within the structure from drifting and when the overhead barrier consists of an eight inch reinforced concrete slab, a protection factor of fifty is reached on the upper level away from direct contribution through the entrance. Increasing the overhead barrier to a twelve inch thick concrete slab raises the protection factor to two hundred. Using an eight inch slab combined with two feet of earth fill, the upper level parking area becomes a shelter area with a protection factor in excess of five thousand. The second and third floors below grade are sufficiently baffled by the ramp sequence and the only special consideration is that of temporarily enclosing the space to exclude drifting fallout particles. If the structure does not have blast doors, the exhaust system would be shut down during shelter occupancy and air forced out vehicle entrances to eliminate possible drifting of fallout dust into shelter area.

If all vehicles are evacuated from this garage the possible shelter occupancy would exceed 30,000 and a considerable area must, therefore, be assigned to house emergency supplies. It recommended that these supplies be stockpiled in least convenient parking stalls on the lowest level. Construction cost of a special storage area would be approximately the same as additional parking space and the space under ramps would only accommodate part of the supplies.

4-4 Office Building Base
(Example C)

4-4.1 Architectural Description

This example is typical of the many new high-rise office buildings where parking is provided on the lower levels of the structure. The stepped platforms in this scheme form a transitional element between the office tower and the open square. Three levels of parking are located here.

The structural system of the office building above has an influence on the structural bay size of the garage below. The long spans giving flexible space to the office building project into the parking area.

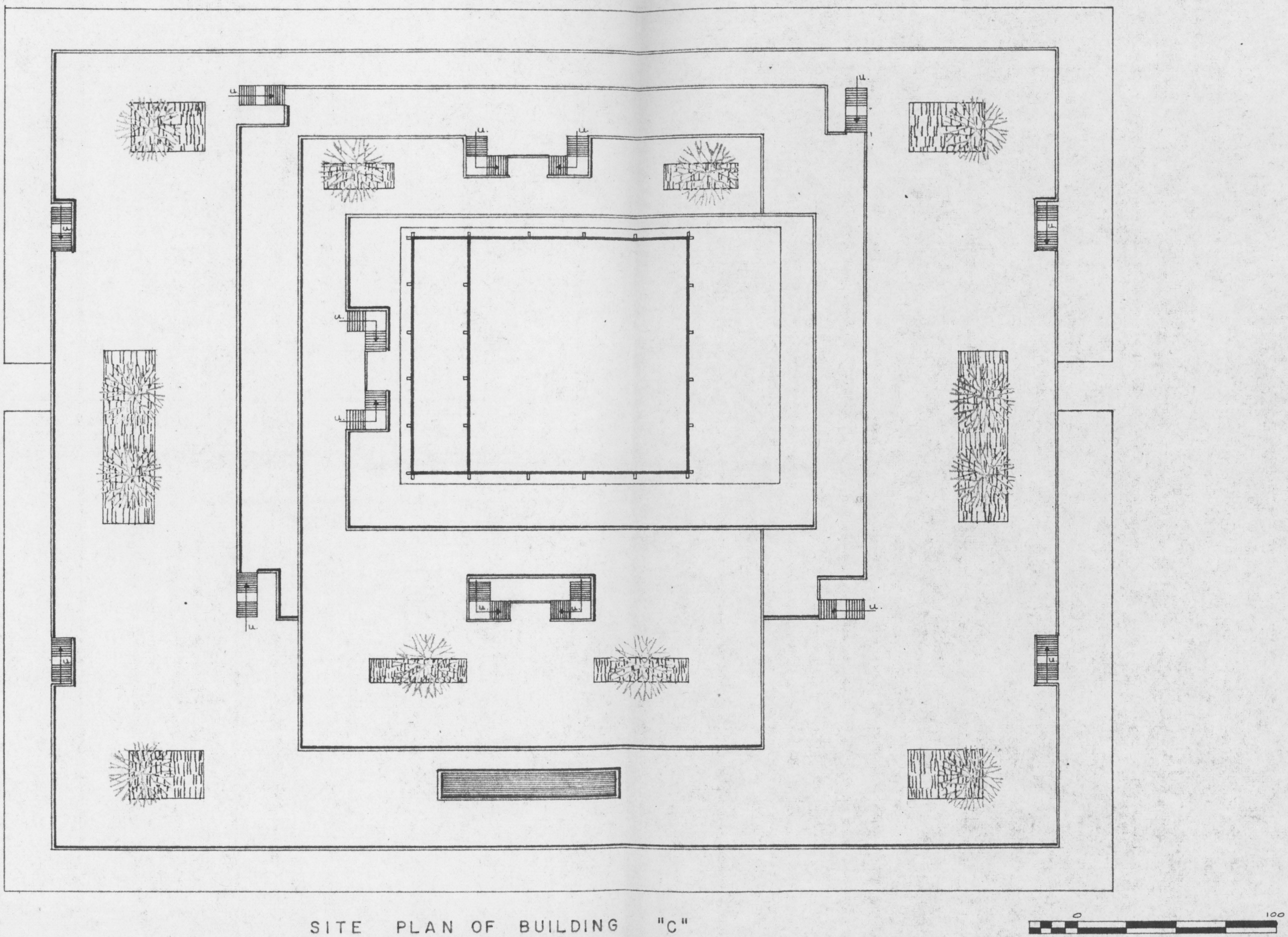
4-4.2 Mechanical System

The open air garage is large enough to require mechanical ventilation. The office building above has heating and cooling equipment located on several levels including one at the lowest floor above the lobby.

Water for the sprinkler system would be supplied from a tank on the roof of the office building.

4-4.3 Thermal and Blast Resistance

As an open air structure, the garage structure itself is not susceptible to overpressures except on the roof area. The superstructure will, however, be subjected to reflected overpressures.



IGURE 4-8 SITE PLAN OF BUILDING "C"

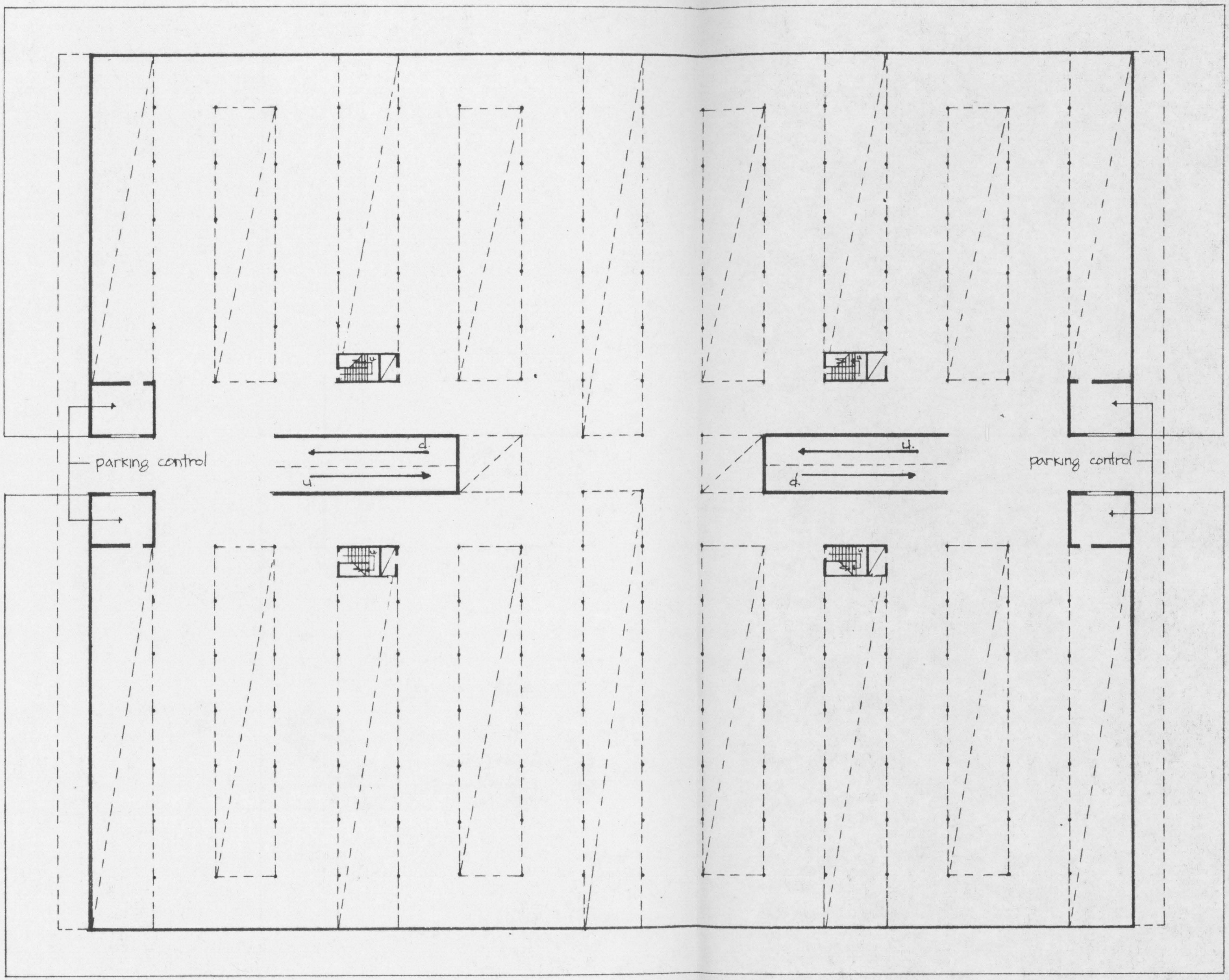
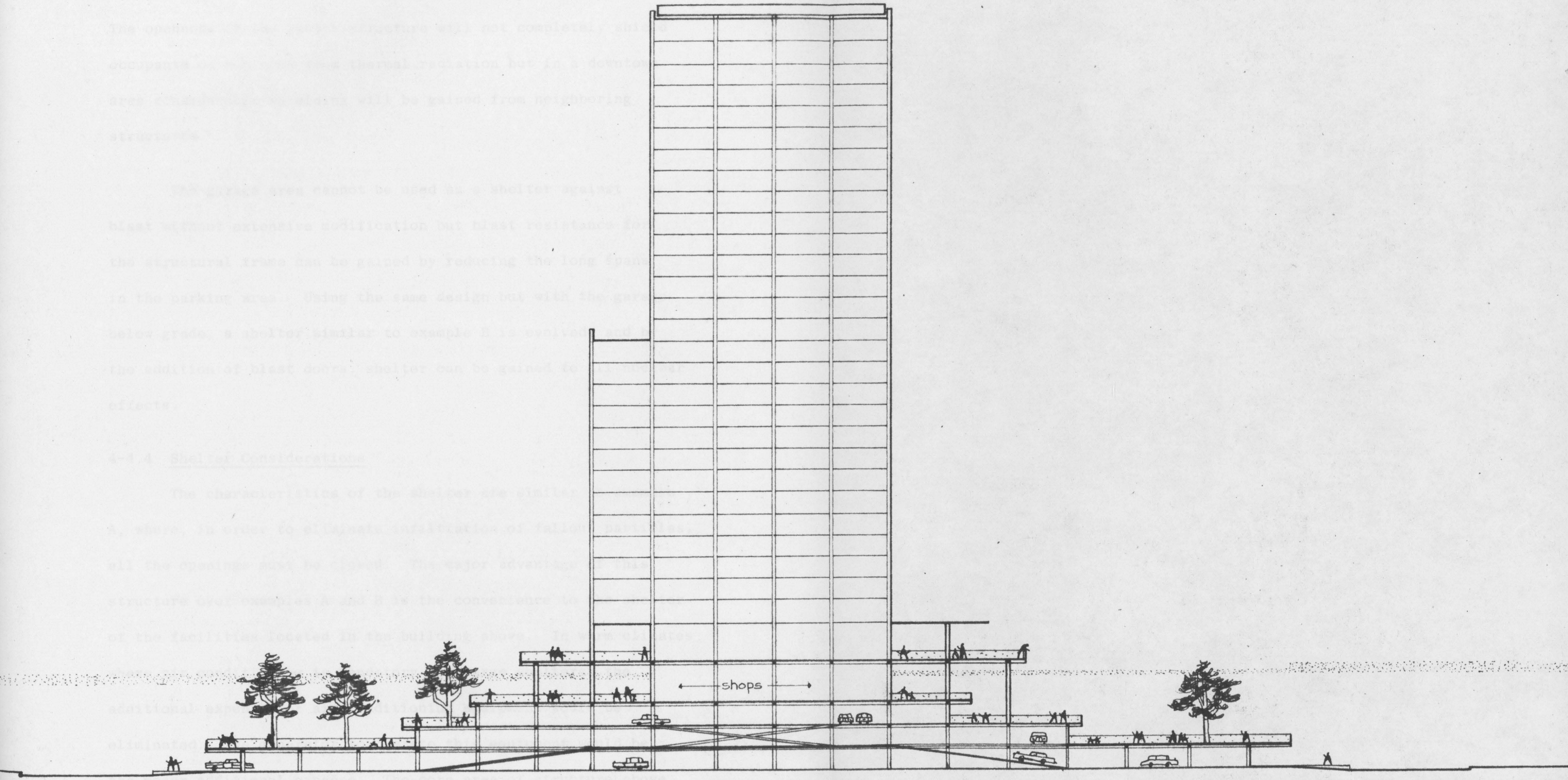


FIGURE 4-9 PLAN AT STREET LEVEL OF BUILDING "C"



IGURE 4-10 SECTION OF BUILDING "C"

0 100

The openness of the garage structure will not completely shield occupants or vehicles from thermal radiation but in a downtown area considerable shielding will be gained from neighboring structures.

The garage area cannot be used as a shelter against blast without extensive modification but blast resistance for the structural frame can be gained by reducing the long spans in the parking area. Using the same design but with the garage below grade, a shelter similar to example B is evolved, and by the addition of blast doors, shelter can be gained to all nuclear effects.

4-4.4 Shelter Considerations

The characteristics of the shelter are similar to example A, where, in order to eliminate infiltration of fallout particles, all the openings must be closed. The major advantage of this structure over examples A and B is the convenience to the shelter of the facilities located in the building above. In warm climates where air conditioning is mandatory for large shelters, the additional expense for air conditioning equipment would be eliminated. The generator to operate this equipment would be the major additional expense. The core area of structure above including the toilet facilities would be available to the shelter area as radiation intensities decrease.

4-5 Integral Type
(Example D)

4-5.1 Architectural Description

The integral type parking garage, though the least common type of parking arrangement employed, represents a scheme exceptionally well suited to a shelter structure. In the example, the parking area is enveloped on all four sides by an office building. The same scheme would work for a motor hotel. A continuous ramped floor provides vertical vehicular circulation and parking space. The corridor around the parking relates the offices directly to the parking as well as to the other facilities of the structure.

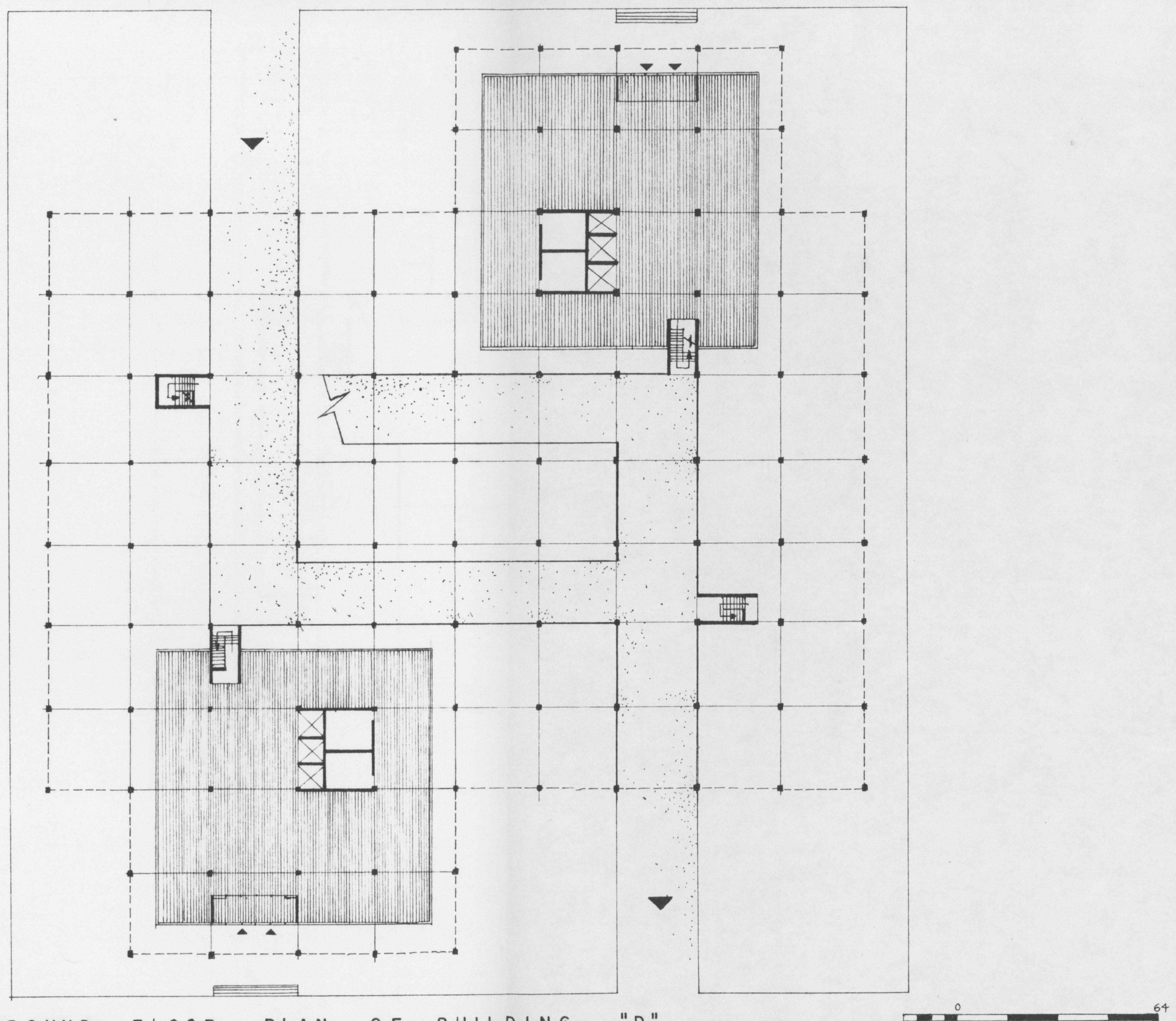
Structurally, the reinforced concrete frame of the garage ties integrally with the office building.

4-5.2 Mechanical System

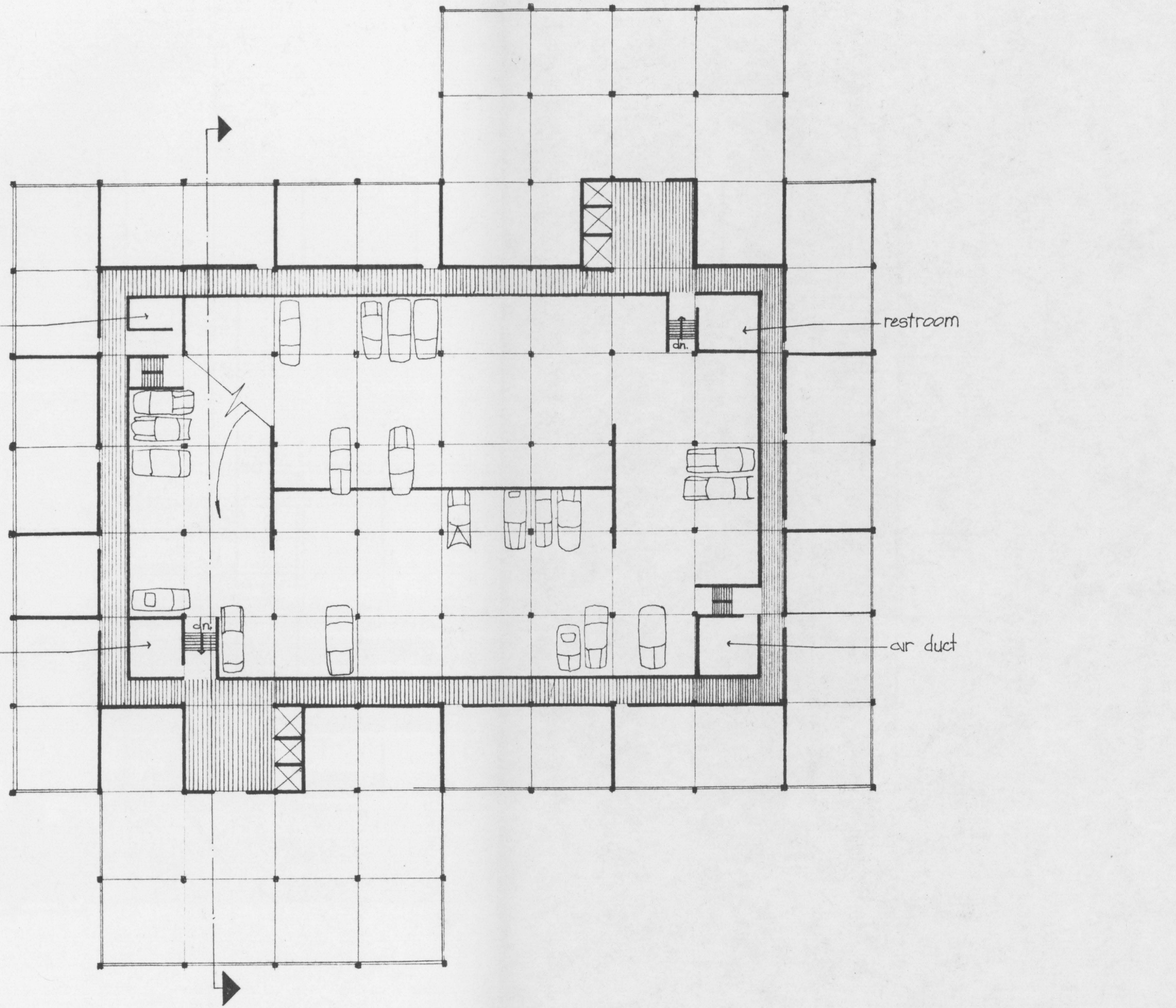
The garage is completely enclosed and, therefore, mechanical ventilation is required. This can be supplemented in an emergency situation by the heating and cooling equipment of the other areas of the building.

4-5.3 Thermal and Blast Resistance

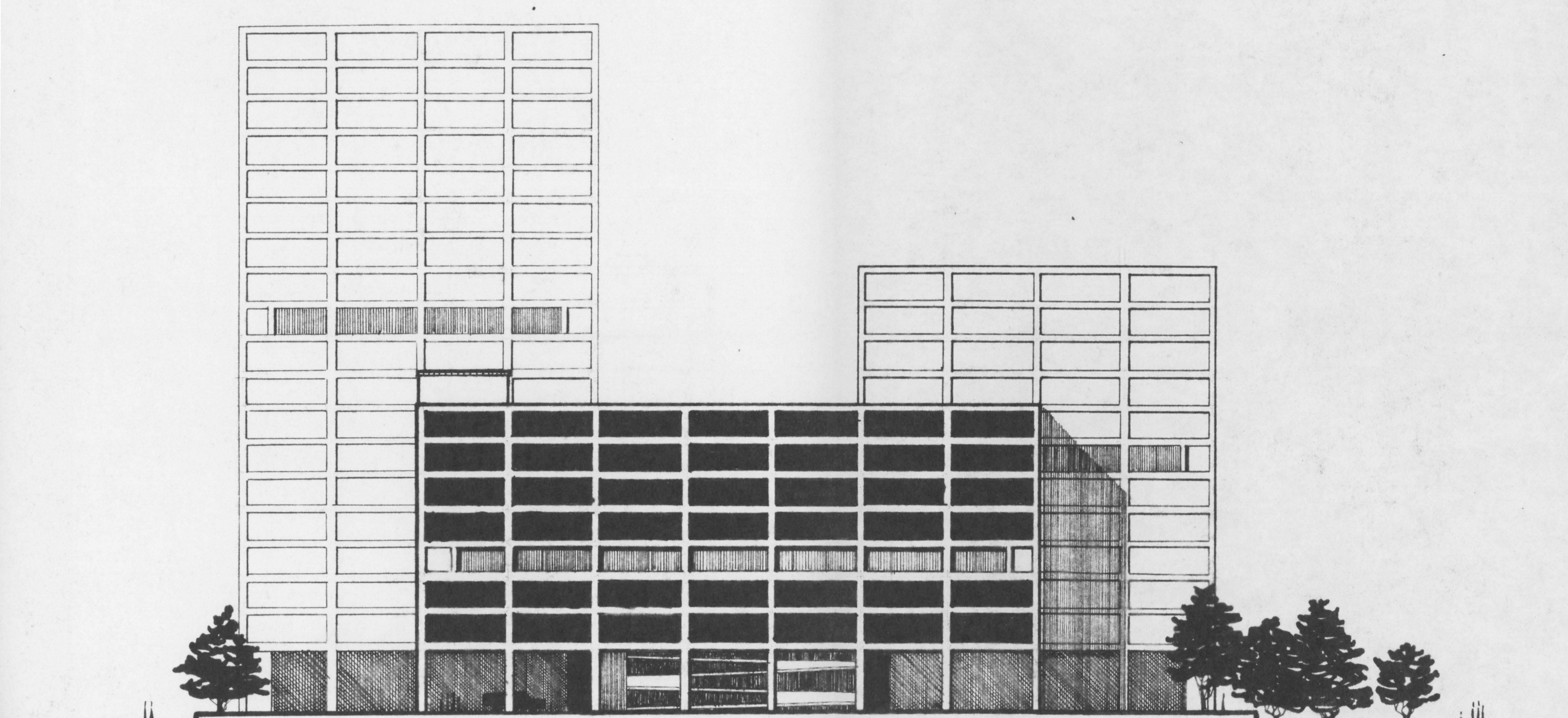
The parking area is completely shielded from the thermal pulse. Blast pressure resistance is minimal with standard office partition construction and because of the



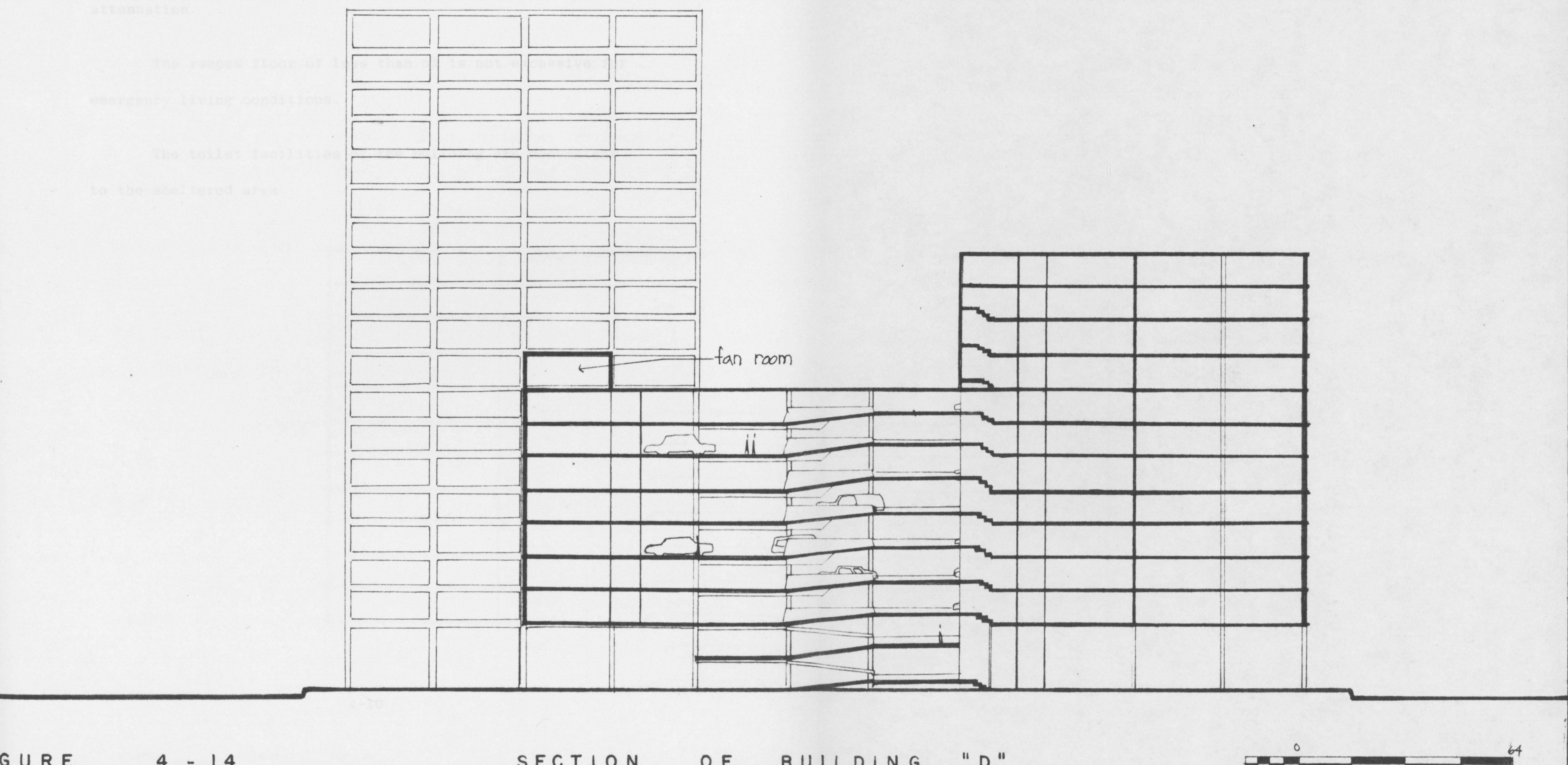
GURE 4 - 11 GROUND FLOOR PLAN OF BUILDING "D"



GURE 4 - 12 TYPICAL FLOOR PLAN OF BUILDING "D"



GURE 4 - 13 ELEVATION OF BUILDING "D"



GURE 4 - 14 SECTION OF BUILDING "D"

enclosing walls, the frame is subjected to higher loadings than example A.

4-5.4 Shelter Considerations

The exterior wall, the office partitions and the two corridor walls offer several mass barriers for radiation attenuation.

The ramped floor of less than 5% is not excessive for emergency living conditions.

The toilet facilities of the building are convenient to the sheltered area.

4-6 Above Ground Type
(Example E)

4-6.1 Architectural Description

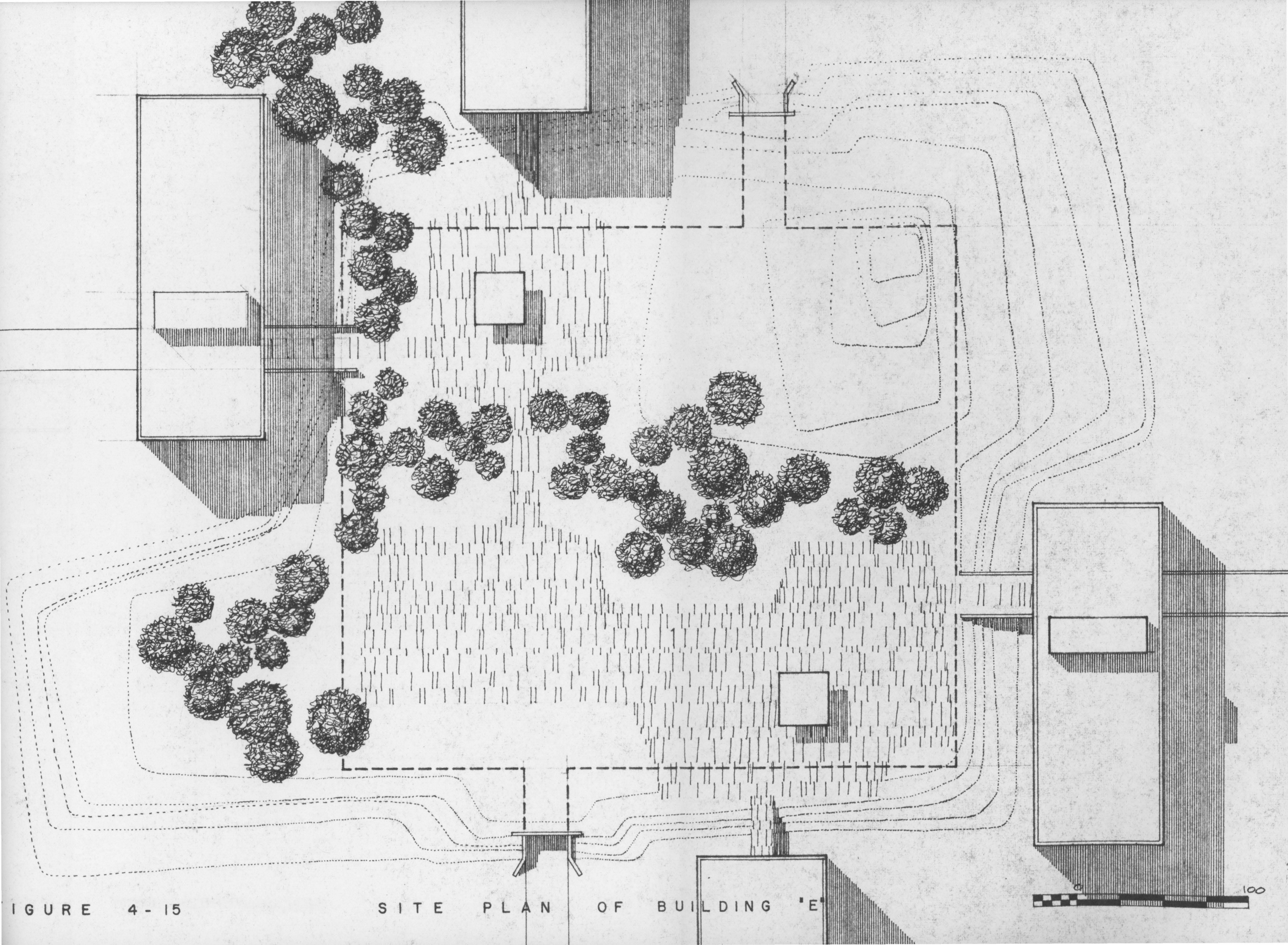
The above ground garage type illustrated shows a garage structure located among new apartment buildings in an urban renewal project. It is assumed that the water level of the ground is high and above ground construction is necessary The solution frees the area used by the garage so that the land is available for playgrounds and green space for the residents of the area. The earth ramparts and landscaping also thoroughly hide the unpleasant view of the parking. The garage is accessible to the ground floor of the apartment buildings by means of covered connecting links.

It is assumed that the residents park their own vehicles. Toilet facilities are provided in the garage structure as a convenience to the people in the park above.

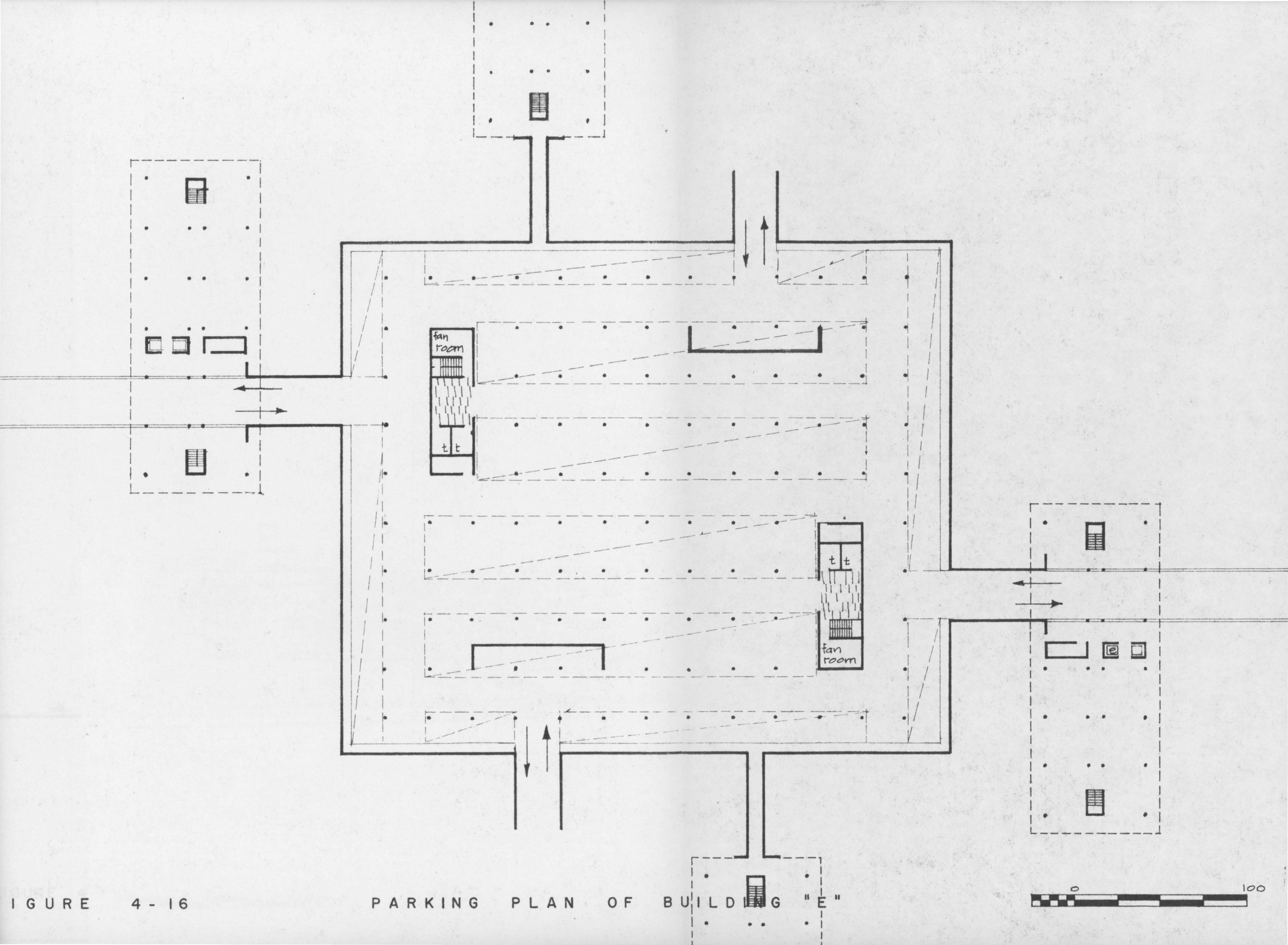
A reinforced concrete flat slab is used on a structural bay size 25' x 28'. Baffle walls at the entrance are concrete bearing walls.

4-6.2 Mechanical System

As a completely enclosed structure, forced mechanical ventilation is used throughout the entire structure. No heating is provided except in the toilet facilities.



IGURE 4- 15 SITE PLAN OF BUILDING 'E'



IGURE 4-16 PARKING PLAN OF BUILDING "E"

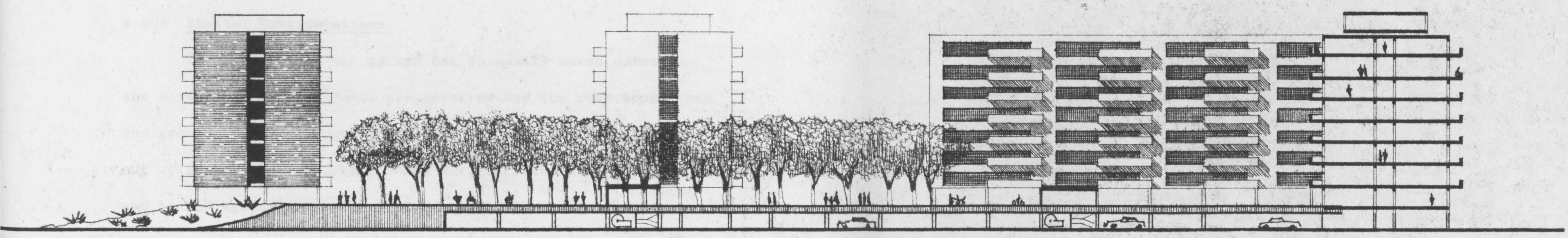
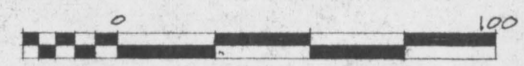


FIGURE 4-17 SECTION OF BUILDING "E"



As in example B fresh air filters are located in low penthouses in the parks above.

A sprinkler system may not be available but the occupants will have access to the water system of the adjoining building.

4-6.3 Thermal and Blast Resistance

As a partially buried structure, the effects of thermal radiation will be negligible on the structure, vehicles or personnel. In order to achieve blast protection for occupants blast doors must be installed at the vehicle and pedestrian entrances and the ventilation openings. Vulnerability to blast pressures can be reduced on the large doors by designing the automobile approaches with right angle bends.

4-6.4 Shelter Considerations

The cars within the garage can be easily moved outside the structure since no ramps are involved and the road approaches and grounds provide adequate space for storing the vehicles without using any street parking. The dirt fill above the shelter and banked against the walls provides excellent mass shielding. Under emergency conditions, baffle walls are provided at the entrance to limit radiation penetration into the shelter. Away from direct contribution through the entrances and assuming no contamination from drifting, the protection factors are in excess of 5000. As radiation intensities decrease the occupants can move into areas of the adjoining apartment building which provides some protection.

4-7 Residential Type
(Example F)

4-7.1 Architectural Description

In the fringe areas of large cities, enclosed parking facilities of the many new low rise apartment buildings offer a good possible shelter location. In the scheme illustrated here, the garage is in a half basement beneath the dwelling units. Parking space for five cars is provided for six units.

The remaining basement area is used for storage, mechanical equipment, and laundry facilities.

A reinforced concrete slab supported on masonry bearing walls forms the structural system and defines the shelter in the basement area.

4-7.2 Mechanical System

The garage area is unheated. The heating and air conditioning units for the apartments are within the shelter area and can be used in emergency conditions.

As conventionally designed, the mechanical system would probably limit the capacity of the shelter. Improvements for the shelter would include installations of a generator as well as fans and filters.

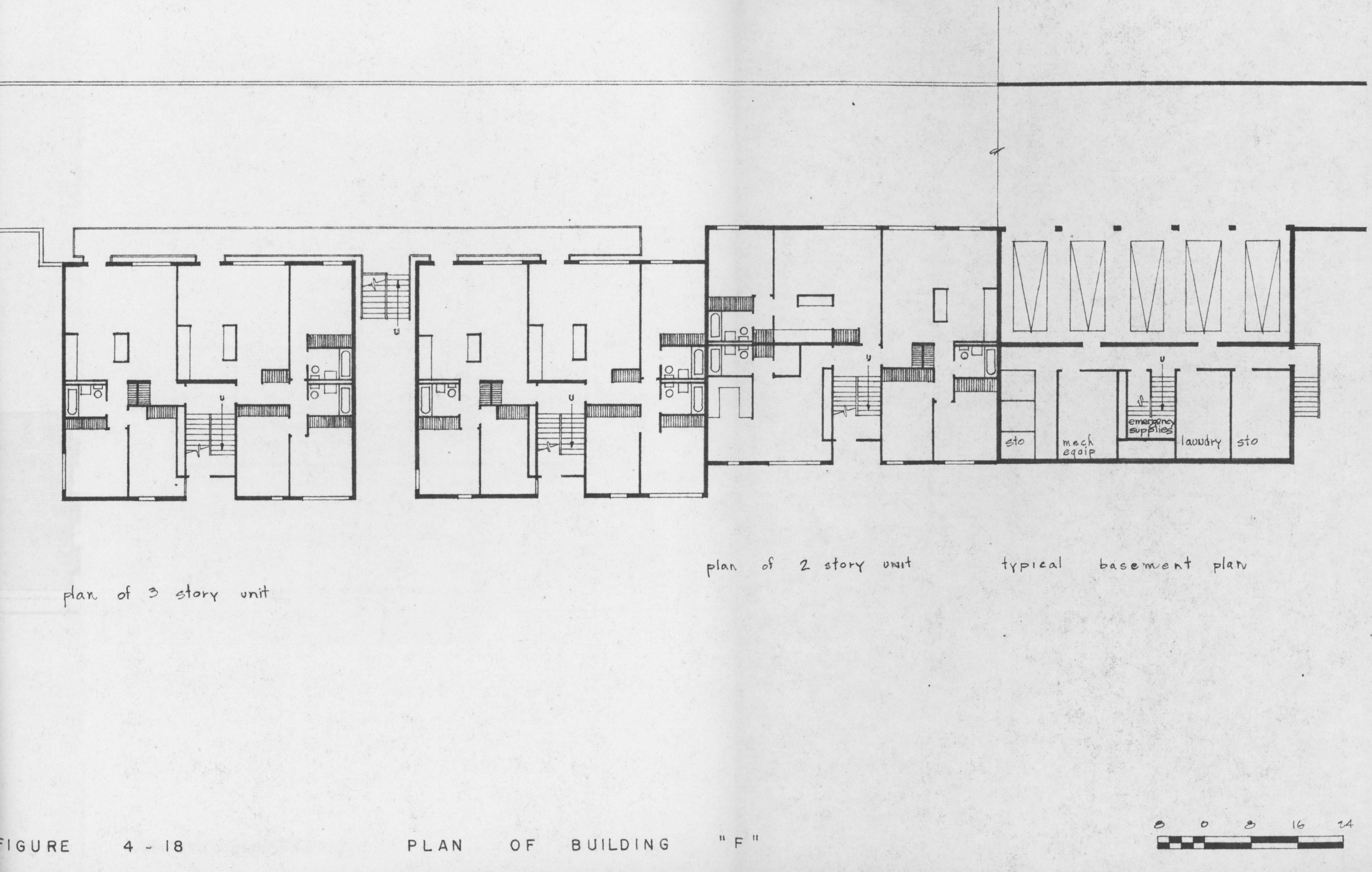
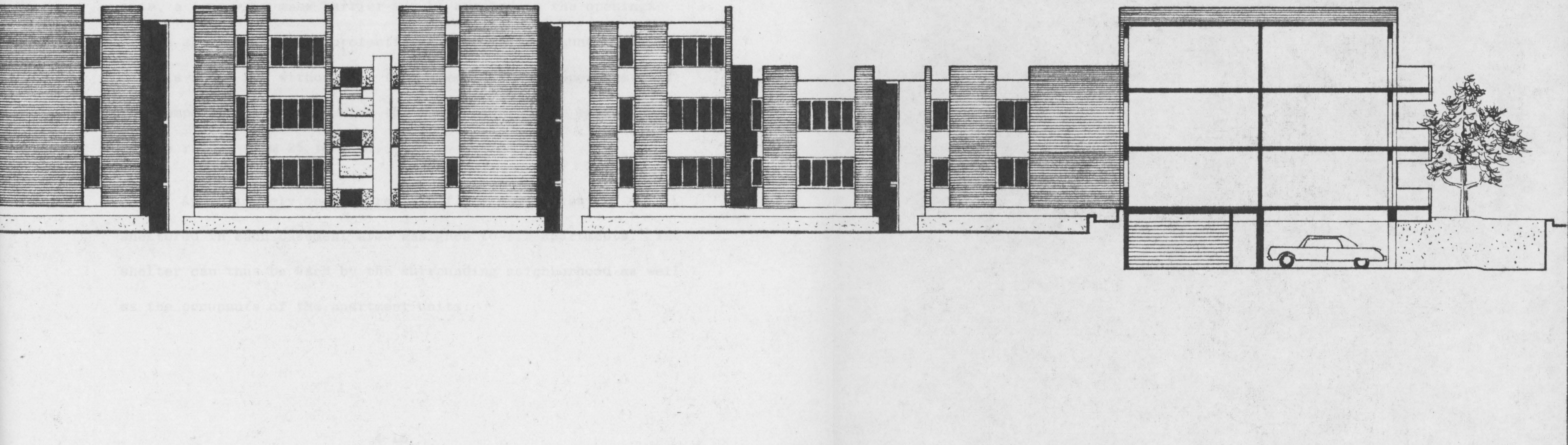


FIGURE 4 - 18 PLAN OF BUILDING "F"



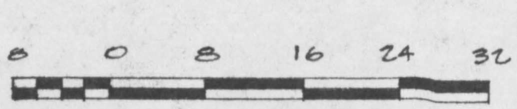


FIGURE 4 - 19 ELEVATION AND SECTION OF BUILDING "F"

4-7.3 Thermal and Blast Resistance

Direct effects of thermal radiation will be negligible. Blast resistance is minimal.

4-7.4 Shelter Considerations

A radiation barrier to ground contribution is provided by the planting area. The structure itself limits the overhead contribution. No permanent mass barrier is located at the vehicle entrance doors, however, the plane of contamination is limited to the driveway area. This area may be covered with vinyl or canvas on a trellis arrangement to prevent an excessive accumulation of fallout debris. Alternatively the drive may be decontaminated or by using solid concrete blocks stored on the site, a temporary mass barrier may be erected in the openings by the shelterees. The protection factor in the laundry-storage area is above 200 without any improvements to the openings. If the temporary wall is erected the protection factor in the garage can be raised from 25 to 100.

Approximately one-hundred and fifty people can be sheltered in each basement area assigned to six apartments. The shelter can thus be used by the surrounding neighborhood as well as the occupants of the apartment units.

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